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Sonifying Urban Rhythms

Towards the spatio-temporal composition of the urban environment

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Abstract

Sonifying Urban Rhythms

Towards the spatio-temporal composition of the urban environment

This thesis is concerned with the composition of the urban rhythms generated by urban design and planning. It recognises the temporal limitations of the graphic urban masterplan, with its tendency of being static and singular in the composition of urban experience. Thus it proposes the integration of rhythm into the urban design and planning process, with the aim to improve the temporal quality of urban design.

In order to represent these urban rhythms, as designed in the graphic masterplan, we propose their sonification. A Sonified Urban Masterplan (SUM) tool was developed, allowing the sonification of multiple layers of maps (raster or vector images) along a number of paths of interest. An urban sonic code was then developed in order to map the relevant graphic urban parameters into sound parameters.

This sonification strategy was applied to the city of Paris as a case study, producing a sonified set of maps whose composition could be 'listened' to over time. Temporal issues concerning human movement, transport infrastructure, activity distribution, and the structuring of urban form and design elements could be represented and heard.

We then investigated the potential of the SUM tool as a design and planning tool. We explored how sound could be used to inform the composition of urban form in both time and space, in order to generate the urban rhythms we may desire to experience.

Thus through the integration of sonification in urban design and planning, this thesis permits the spatio-temporal representation and composition of urban form. It allows urban designers and planners to compose future urban rhythms and improve the temporal quality of our urban environments. Furthermore, the potential of this tool in other fields has also be recognized, for example in music and the composition of multi-layered open graphic scores.

Keywords:

Urban design and planning, Time Geography, Soundscape Studies, Rhythmanalysis, urban rhythms, urban masterplan, graphic musical score, computer-aided composition, image sonification, sound design

Abstract

La Sonificazione dei Ritmi Urbani

Verso la composizione spazio-temporale dell'ambiente urbano

Questa tesi riguarda la composizione dei ritmi urbani generati dalla progettazione urbana e dalla pianificazione. Riconosce i limiti temporali del *masterplan* grafico urbano, che ha la tendenza ad essere statico e singolare nella composizione dell'esperienza urbana. Pertanto, propone l'integrazione del ritmo nel processo di progettazione urbana per migliorare la qualità temporale dello spazio urbano.

Per rappresentare questi ritmi urbani prodotti dalla progettazione grafica, si propone la loro sonificazione. Uno strumento, *Sonified Urban Masterplan* (SUM), è stato sviluppato, consentendo la sonificazione di strati multipli di mappe (immagini raster o vettoriali) lungo una serie di percorsi di interesse. Un codice urbano sonoro è stato dunque sviluppato al fine di mappare i relativi parametri grafici urbani nei parametri del suono.

Questa strategia è stata applicata alla sonificazione della città di Parigi come un caso di studio, producendo una serie di mappe sonificate, la cui composizione spazio-temporale potrebbe essere 'ascoltata'. Questioni di carattere temporale riguardo al movimento umano, alle infrastrutture dedicate al trasporto, alla distribuzione delle attività, alla struttura della forma urbana e degli elementi di design, possono essere rappresentate e ascoltate.

Si è quindi studiato il potenziale dello strumento SUM come strumento di pianificazione e progettazione. Si è esplorato come il suono potrebbe essere utilizzato per comporre la struttura urbana nel tempo e nello spazio, in modo da generare i ritmi urbani che si desiderano sperimentare.

Dunque, Attraverso l'integrazione della sonificazione nell'urbanistica e nella pianificazione, questa tesi propone la rappresentazione spazio-temporale e la composizione della forma urbana. Permette ai progettisti e pianificatori urbani di comporre ritmi urbani futuri e migliorare la qualità temporale dei nostri ambienti urbani. Infine è anche riconosciuta la potenziale di questo strumento in altri campi, come ad esempio in un approccio grafico e multistrato alla composizione musicale.

Parole chiave:

Progettazione urbana e pianificazione, Geografia del Tempo, Studi del Paesaggio Sonoro, *Rhythmanalysis*, ritmi urbani, *masterplan* urbano, partitura grafica musicale, computer-aided composition, sonificazione d'immagine, design sonoro

Abstract

La Sonification de Rythmes Urbains

Vers la composition spatio-temporelle de l'environnement urbain

Cette recherche s'intéresse à la composition de rythmes urbains générés par la conception et la planification urbaine. Elle reconnaît les limitations temporelles du plan d'urbanisme qui a tendance à être statique et singulier dans la composition de l'expérience urbaine. Ainsi, elle propose l'intégration du rythme dans le processus de conception urbaine, dans le but d'améliorer la qualité temporelle de l'espace urbain.

Pour représenter ces rythmes tels qu'ils sont produits dans la conception graphique, nous proposons leur sonification. Un outil de sonification des plans d'urbanisme (l'outil SUM) a été développé, et permet la sonification de plusieurs couches de cartes (images raster ou vectorielles) le long d'un certain nombre de parcours d'intérêt. Un code sonore urbain a été développé dans le but de relier les paramètres graphiques urbains aux paramètres sonores.

Nous avons pris comme cas d'étude la ville de Paris et avons appliqué cette stratégie à sa sonification, afin de produire un ensemble de cartes sonifiées de la ville dont la composition spatio-temporelle pourrait être "écoutée". Des questions temporelles concernant le mouvement humain, les infrastructures de transport, la distribution d'activité, la structuration de la forme urbaine et les éléments de conception, peuvent être représentées et entendues.

Nous avons ensuite étudié le potentiel de l'outil SUM comme outil de conception et de planification. Nous avons exploré comment le son peut être utilisé pour informer la composition de la forme urbaine à la fois dans le temps et dans l'espace, afin de générer des rythmes urbains dont nous désirons faire l'expérience.

Ainsi, grâce à l'intégration de la sonification dans la conception et la planification urbaine, ce travail de recherche permet la représentation spatio-temporelle et la composition de la forme urbaine. Il permet aux concepteurs et planificateurs urbains de composer les futurs rythmes urbains et d'améliorer la qualité temporelle de nos milieux urbains. De plus, le potentiel de cet outil dans d'autres domaines a également été reconnu, par exemple comme une approche graphique et multi-temporelle de la composition musicale assistée par ordinateur.

Mots-clés:

Design urbain, planification urbaine, géographie du temps, études de paysages sonores, philosophie de Rythmanalyse, rythmes urbains, masterplan urbain, partition graphique musicale, composition assistée par ordinateur, sonification de l'image, design sonore

Début de Résumé Français
Start of French Resume

La Sonification de Rythmes Urbains

Vers la composition spatio-temporelle de l'environnement urbain

Sara ADHITYA

Introduction

Cette thèse identifie le rythme comme une qualité importante de nos environnements urbains. Définis comme l'interaction d'un espace, un temps et une énergie (Lefebvre, 1992), les rythmes urbains existent en diverses formes : l'environnement naturel, la forme urbaine, les infrastructures de transport, l'activité urbaine et les éléments de design urbain. La ville est une composition de ces rythmes à différentes échelles spatiales (du régional au local) ainsi que les échelles temporelles (de rythmes annuels à la vie quotidienne). La vie urbaine est une expérience rythmique et donc les rythmes urbains peuvent être utilisés comme un indicateur de la qualité spatio-temporelle de l'environnement urbain.

En définissant les qualités rythmiques de l'environnement urbain, nous regardons vers les domaines de la Géographie du temps, la philosophie de Rythmanalyse et les études de paysages sonores. Alors que les géographes du temps ont la proposé la cartographie objective des flux urbains spatio-temporels, le philosophe français Henri Lefebvre a orienté notre attention vers leur expériences phénoménologiques, et les écologistes sonores nous ont conseillé de littéralement écouter le monde autour de nous.

Cependant, dans la pratique spatiale de la conception et de la planification urbaine, la temporalité peut être difficile à capturer. La représentation temporelle est limitée dans le plan graphique d'urbanisme. Ainsi, nous proposons la moyenne temporelle du son, et en particulier la technique de sonification - la représentation des données par des moyens auditifs - afin d'articuler ses rythmes.

Nous cherchons à intégrer le rythme dans le processus de conception et de planification urbaine, à travers le développement d'un outil « SUM » pour la sonification des cartes d'urbanisme existantes (par l'importation des images raster) ainsi que la composition graphique des nouvelles cartes (à travers la création des objets vecteurs). Avec l'aide d'un code sonore urbain, nous pouvons traduire les éléments graphiques urbains d'intérêt en sons, et donc articuler leur composition dans le temps ainsi que dans l'espace.

Grâce à ce processus de sonification, nous visons à créer un moyen de représenter les effets temporels de notre environnement urbain existant, révélant les problèmes urbains rythmiques actuels. En même temps, nous fournissons les moyens pour les concepteurs urbains de graphiquement composer les nouveaux rythmes, dans le but d'améliorer la qualité temporelle des futurs designs urbains. Alors que les effets d'une approche plus rythmique à du design urbain ne peuvent être révélés qu'avec le temps, la capacité de représenter ces rythmes est un pas en avant en nous permettant de prendre le contrôle du temps et de composer notre vie quotidienne. Comme réalisé par Lefebvre:

"... La ville ne sera repensée et reconstruite sur ses ruines actuelles lorsque nous aurons bien compris que la ville est le déploiement du temps." [2]

[2] Lefebvre H., *Writings on Cities*, in Kofman, E. and Lebas, E. (trans.), Basil Blackwell, Oxford, 1995: 16

Structure de la thèse

Dans le développement d'une « Rythmanalyse sonifiée » de notre environnement urbain, cette thèse est structurée en quatre parties principales :

Partie 1 : Théorie
Nous identifions les rythmes pertinents pour le design et la planification urbaine, en explorant comment les rythmes urbains ont été représentés, analysés et organisés dans des domaines connexes : la philosophie; la géographie du temps, et les études de paysages sonores.

Partie 2 : Méthodologie
Nous essayons de «capturer» les rythmes urbains identifiés avec le son et la technique de sonification. Nous développons une stratégie de sonification urbaine impliquant la création d'un outil « Masterplan Urbain Sonifié » (SUM) capable de sonifier des images existantes ainsi que la composition graphique de nouveaux plans.

Partie 3 : Applications
Représentation : Tout d'abord, nous appliquons l'outil SUM à notre cas d'étude de la ville de Paris, afin de produire un ensemble de cartes sonifiées de la ville qui pourrait être "écoutée". Nous comparons la composition spatio-temporelle des différentes parties de la ville en fonction de leurs divers éléments urbains : les infrastructures de transport ; les activités urbaines ; les formes urbaines et les éléments de design.

Analyse : Deuxièmement, nous explorons la possibilité d'une « Rythmanalyse sonifiée » à travers la sonification des rythmes quotidiens d'un groupe de participants à Paris, puis d'évaluer l'efficacité d'une telle technique.

Partie 4 : Conception
Enfin, nous utilisons l'outil SUM dans le développement d'un projet de design urbain, générés par des rythmes musicaux.

Composants de thèse

En raison de sa nature multidisciplinaire, cette thèse se manifeste dans les formes suivantes:

- **A.** Un volume théorétique explorant le concept de rythme urbain
- **B.** Un logiciel pour la sonification d'image et composition graphique assistée par ordinateur
- **C.** Un ensemble des « instruments urbains » pour la sonification de chaque ensemble de données urbaines
- **D.** Une vidéo présentant le code sonore urbain et comment on peut «jouer» la ville
- **E.** Une collection de sonifications audio-visuelles de divers éléments urbains
- **F.** Une «Rythmanalyse sonifiée » des rythmes typiques de la vie quotidien à Paris
- **G.** Les réponses du public général et des professionnels urbains
- **H.** Un projet de design urbain généré par des rythmes musicaux

Partie 1 : Identifier de Rythmes Urbains

Introduction

«Partout où il y a interaction entre un lieu, un temps et une dépense d'énergie, il y a du rythme.» [3]

La première partie de cette thèse pose les questions fondamentales : qu'est-ce que sont les rythmes urbains, et pourquoi sont-ils importants pour la qualité du design urbain?

Tout d'abord, nous discutons de la nature des rythmes et les types de rythmes pertinents à nos environnements urbains. Nous explorons de leur pertinence pour la durabilité de la ville et la raison pour laquelle nous voulons «recomposer» ces rythmes.

Pour expliquer cela, nous explorons les différents domaines dans lesquels le rythme a déjà été étudié en relation avec l'environnement urbain : la géographie du temps ; la philosophie ; et les études de paysages sonores.

Nous découvrons qu'il y a eu diverses tentatives pour développer une théorie de *Rythmanalyse*, notamment par le philosophe français Henri Lefebvre, qui a proposé l'élaboration d'une «science analytique» de rythmes, peu de temps avant sa mort en 1991.

Ainsi, nous continuons la recherche de Lefebvre en explorant les différentes manières dont les rythmes sont actuellement organisés dans la ville et comment ils sont représentés. Nous arrivons à la question : comment pouvons-nous représenter ces rythmes urbains afin de les analyser et ensuite de les composer?

[3] *'Everywhere where there is interaction between a place, a time and an expenditure of energy, there is rhythm.'*
Lefebvre, H. *Rhythmanalysis: Space, Time and Everyday Life*, Continuum, London, 2004, p.15

Chapter 1 : Les Rythmes de la Ville

Le rythme a toujours marqué la vie des gens, mais comme l'a reconnu Lefebvre « il *est devenu visible que l'urbanisation a permis l'observation des aspects uniformes et répétitifs de la vie sociale*» [4]. Les processus d'urbanisation ont influencé la nature de nos rythmes quotidiens. Parfois, les infrastructures urbaines et leurs horaires respectifs travaillent à soutenir nos besoins rythmiques, et parfois nous souffrons de leurs limites spatiales temporelles. La vie urbaine est souvent décrite comme une «composition rythmique», grâce notamment à quatre principaux groupes de rythmes urbains observés : celles des gens ; du corps ; de la mobilité ; ainsi que les rythmes de la nature.

Les rythmes des gens

Décris comme «la routine, les flux quotidiens de gens à travers l'espace et le lieu», les rythmes se composent des tâches quotidiennes routinières de personnes telles que les rythmes sont structurés par leurs calendriers respectifs. Les navetteurs, les acheteurs, les étudiants, les touristes ont tous leurs horaires spécifiques, contrairement à des rythmes moins ordonnés par des chômeurs et des sans-abri. Ces rythmes sont soumis à des rythmes naturels de jour comme de nuit et des saisons, ainsi que les rythmes synthétiques d'horaires de transports publics, heures d'ouverture et les heures d'éclairage.

Les rythmes du corps

Les rythmes corporels internes comprennent notre respiration et notre circulation sanguine. Le mode de réalisation des rythmes est reconnu comme un élément central de notre compréhension et la mesure des rythmes environnementaux. En même temps que nous pouvons comparer et contraster nos rythmes internes avec les rythmes externes, nous pouvons également réglementer par la formation répétitive - ce que Lefebvre appelle «dressage», également appelé «entraînement». «L'absorption» des rythmes externes dans le corps par la répétition et la pratique permet à son adoption comme «seconde nature», comme l'apprentissage d'une nouvelle danse. La détection de rythmes corporels est essentielle à notre expérience subjective et culturelle d'un lieu.

Les rythmes de la mobilité

Les rythmes les plus évidents de la mobilité sont ceux du transport, avec les réseaux de transports collectifs de train, tram et bus, les rythmes plus indépendants de la voiture et le vélo, ou le rythme le plus corporel de la marche. La régulation de ces flux de circulation est mise en œuvre sous la forme de feux de circulation, les limitations de vitesse, l'aménagement des routes et des conventions de conduite. Ces rythmes sont caractérisés par leur tempo et régularité, et déterminée par le mode et style de voyage.

[4] Felski, 2000, p.16

Les rythmes «non-humains»

Ces rythmes ont lieu dans les rythmes du monde non-humain. Les plus évidents sont les grands rythmes cycliques de la nature - climatiques, géologiques et géomorphologiques - les cycles de la lune et du soleil, des marées et des océans. Moins visibles sont ceux de la flore et de la faune, des énergies et même des objets qui semblent «seulement lents par rapport à notre époque, à notre corps, la mesure des rythmes» [5]. Comme l'a reconnu Lefebvre, il n'y a «rien d'inerte dans le monde».

Ainsi nos vies urbaines peuvent être considérées comme l'interaction de ces différents rythmes humains et non-humains. Comme identifié par Crang, «le lieu urbain où le site est composé et caractérisé par des motifs de ces multiples battements.» [6] Ainsi le lieu lui-même peut être considéré comme l'intersection dynamique du temps et de l'espace - l'interaction des flux urbains et de la forme urbaine.

Les implications pour le design urbain

Comme la structure spatiale dans laquelle nous vivons nos activités quotidiennes, la conception de nos villes joue un rôle inévitable dans la détermination de nos rythmes quotidiens. Ensuite, la composition des formes et des infrastructures compose les flux temporels des citoyens et de leurs activités relatives. Ainsi, chaque ville peut être observée comme ayant ses propres caractéristiques rythmiques grâce à sa structure urbaine.

Les rythmes de la structure urbaine comprennent la morphologie de la forme elle-même (connue comme le tissu urbain), les activités urbaines contenues, les réseaux routiers et les systèmes d'infrastructure qui les relient. Ces rythmes ont un effet inévitable sur les questions d'accessibilité et de connectivité du mouvement humain, et l'activité urbaine résultante. La forme de nos villes devrait idéalement soutenir à la fois les rythmes de nos vies quotidiennes et celles de notre environnement naturel de façon durable. Cependant les développements technologiques - la voiture, les infrastructures à haute vitesse, et la virtualité de l'internet - ont changé les relations entre l'espace et le temps, et en conséquence nos besoins rythmiques spatiaux. La conception spatiale de nos villes est souvent plus lente à s'adapter, et les problèmes urbains résultants comprennent la congestion du trafic et l’expansion urbaine. Ainsi, de nouvelles approches de design urbain sont nécessaires pour répondre à ces nouveaux rythmes.

Nous identifions de nombreux problèmes urbains qui peuvent être mesurés en rythme. Arythmie, ou des rythmes contradictoires, peuvent indiquer des problèmes d'infrastructure de la congestion, la connectivité et l'accessibilité. Une absence de rythmes peut indiquer des zones «mortes» dans la ville a besoin de revitalisation. Ainsi, le rythme peut être utilisé comme une approche vers la régénération urbaine et de la réanimation de l'espace social et de lieu. Etant donné le nombre de problème sociaux, culturels et environnementaux identifiable en termes de rythme, nous proposons une approche rythmique à leur résolution contre la crise de la durabilité urbaine actuelle.

[5] Lefebvre, 2004, p.17 in Edensor, 2010, p.7
[6] Crang, 2001

Chapter 2 : L’analyse de rythmes urbains

L'analyse des rythmes urbains peut être trouvée dans les domaines connexes suivants, qui seront discutés ci-dessous : la philosophie, et la théorie de la Rythmanalyse développée par Bachelard dans les années 1930 et plus tard par Lefebvre ; la géographie du temps, et l'appel à la temporalité dans la cartographie géographique dans les années 1970 ; et les études de paysages sonores, concernés par la qualité acoustique de l'environnement urbain.

«L’interaction espace-temps contraint» de Hägerstrand et le «lieu temporel » de Lefebvre révèlent une différence fondamentale entre les deux approches analytiques. La première est objective dans son point de vue externalisée, tandis que la seconde est subjective dans son internalisation. Pourtant, la ville n'est ni une machine rythmique, ni un théâtre de l'expérience corporelle.

Alors que la cartographie objective du mouvement humain spatio-temporel dans la géographie du temps est utile pour une meilleure compréhension des schémas de l'activité humaine dans un lieu particulier, cette méthode objective peut être vue comme ignorant l'aspect expérientiel de l'espace-temps.[7]

Au même temps, l'approche subjective de Rhythmanalyse de Lefebvre à la compréhension de la mise en forme de l'expérience humaine dans la vie quotidienne, nécessite encore beaucoup de développement pour extraire de sa proposition une «science analytique». Lefebvre a proposé l'écoute de la ville « comme un assemblage de rythmes différents. » [8] Si nous devions prendre cette écoute littéralement, ce rythme devrions-nous entendre ?

Le paysage sonore montre un grand potentiel dans la communication de certains rythmes environnementaux. Cependant, alors qu'il peut agir comme un indicateur de rythmes sonores dans l'environnement, tous les rythmes ne peuvent être entendus. En outre, il est difficile d'isoler les sons des rythmes que nous voulons des rythmes que nous ne voulons pas. Ces questions seront abordées dans la deuxième partie, et dans notre développement d'une technique pour l'analyse avec une prise en compte à la fois interne et externe du rythme.

[7] Tim Edensor, 2010, p.2
[8] Crang, 2001, p.189

Chapter 3 : L’organisation de rythmes urbains

Aussi variées que les types de rythmes urbains identifiés, sont les diverses tentatives de les organiser. Dans ce chapitre, nous discutons d'abord de leur design physique dans la planification urbaine, avant d'explorer leur contrôle par des mouvements politiques et culturels, et le rôle de régulariser des politiques sociales mises en œuvre par les « Bureaux du Temps » du gouvernement de la ville.

Figure 3.1 : La brochure du Bureau de Temps de la Marie de Paris[9]

Selon Lefebvre, pour que le changement rythmique se produise dans la société, *«un groupe social, une classe ou une caste doivent intervenir en imprimant un rythme sur une époque, que ce soit par la force ou d'une manière insinuante. »* [10] Nous avons vu comment les mouvements culturels et politiques sociales récents tentent de résister et de manipuler les paramètres temporels de la vie urbaine. Il est également clair comment la conception de systèmes d'infrastructures de transport et les horaires déterminer les rythmes urbains. Souvent considéré comme statique et donc «sans temps», le rôle de l'espace dans l’organisation du temps ne doit pas être sous-estimé. Comme reconnu par Crang : *«En voyant le temps en termes d'espace est de le soumettre à l'uniformité d'une vue dominante, à permettre son administration. »* [11]

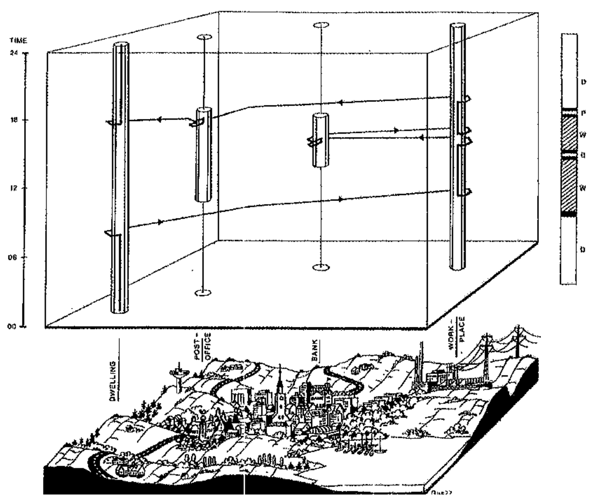
[9] Marie de Paris, *The Time Office of the City of Paris,* 2006
[10] Lefebvre, 2004, p.14 in Edensor, 2010, p.11
[11] Crang, 2001, p.204

Chapter 4 : La représentation de rythmes urbains

Dans ce chapitre, nous explorons les techniques utilisées pour représenter le temps dans le design urbain ainsi que les autres domaines connexes. Selon l'urbaniste Peter Bosselmann, il existe deux types de représentation urbaine : conceptuelle et empirique. [12] L'une traite de paramètres physiques tels que la structure, la forme et la volumétrie, l'autre de l'expérience. La pratique appliquée du design urbain exige tous les deux. Cependant, la domination des techniques de représentation visuelle plus souvent privilégie les effets spatiaux plutôt que temporelle.

Le masterplan urbain graphique est la technique de représentation principale dans le domaine appliqué au design et à la planification urbaine. Bien que concerné par l'organisation et le design des objets statiques dans l'espace, son effet sur le système urbain dans son ensemble est fondamentalement temporel. Étant intrinsèquement statique, le masterplan urbain traditionnel a ses limites dans la conception des systèmes urbains dynamiques. Cela nous amène à remettre en question la façon dont nous pouvons concevoir quelque chose temporelle avec une technique de représentation statique.

Ainsi, cette section explore les techniques de représentation temporelle utilisées dans le design et la planification urbaine, avant d'explorer les domaines de la géographie du temps et d'étude de paysages sonores. Nous explorons les diagrammes espace-temps de Hägerstrand, la notation espace-temps de Whyte, la visualisation 2D et 3D des flux urbains et les tentatives récentes de représentation de données en temps réel, ainsi que le développement récent de cartographie sonore.



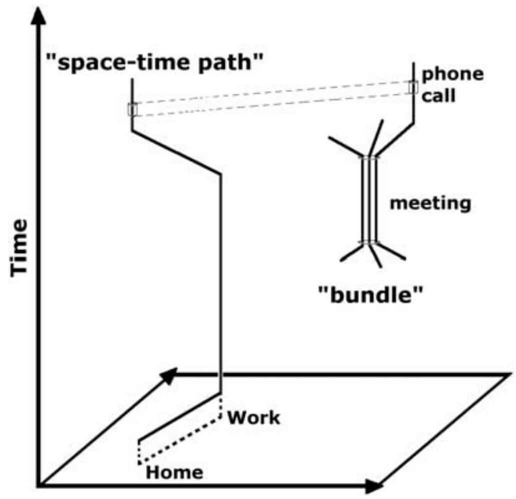


Figure 4.1[13] *et Figure 4.2*[14]*: Les diagrams d'espace-temps de Hägerstrand*

[12] Bosselmann et al, 1993

[13] Image by urbanTick / Taken from Lentrop, 'A Time-Geographic Simulation Model of Individual Activity Programmes', in Carlstein, *Timing Space, Spacing Time*, 1978. [Accessed September 2012]

[14] Vrotsou et.al., *2D and 3D Representations for Feature Recognition in Time Geographical Diary Data*, Information Visualization 2010, v. 9, p.275

Les problèmes de la représentation spatio-temporelle

«Le temps est une expérience de flux plutôt que d'être une série d'images statiques enchaînées dans une séquence. La critique sur les modèles de l'espace et du temps ne travaille donc pas seulement au niveau de l'expérience, mais aussi celui de la représentation. Nous avons besoin d'un sens de l'événement et du processus du temps, plutôt que de laisser que la pensée soit dominée par des représentations statiques ». [15]

Crang

Parmi les différentes techniques de cartographie que nous avons présentées, la notion de «représentation objective» et l'imposition d'un «cadre spatio-temporel de référence» du point de vue externe d'un observateur sont contradictoires. Ils peuvent en général être critiqués pour leur implication simpliste d'une «temporalité abstraite singulière», qui représente «l'espace-temps d'un observateur externe à l'extérieur» et en ignorant le fait que «*les êtres humains vont expérimenter eux-mêmes et leurs environnements à partir de différents points de vue*». [16]

La géographie de temps a été «admirée pour sa potentialité de représentation et d'offrir un départ conceptuel et méthodologique solide pour la recherche empirique» [17]. Cependant, il reste encore à atteindre la représentation multidimensionnelle d'espace-temps qui est exigée par la corporalité. La ligne dessinée a un manque de corporalité, présentant « *des rythmes individuels plutôt unsensual et désincarnés.* » [18]

Idéalement, « chaque trajectoire devrait en fait être placé dans ses propres contextes d'espace-temps, et représentée d'une manière déterminée.» Pour y parvenir en tant qu'observateur d'un diagramme temps-géographique, nous sommes obligés de « nous placer à l'intérieur de la ligne de chaque trajectoire en lieu de les observer depuis l'extérieur par rapport aux coordonnées de temps et d'espace représentés dans le diagramme. [19]

Tel que Deleuze avait reconnu, le problème est que «*le mouvement (le temps) est différent à la distance parcourue par une ligne qui peut être divisée à l'infini (l'espace).* » [20] Ainsi, le mouvement, contrairement à l'espace, «*ne peut pas être divisé sans changer qualitativement chaque fois qu'il soit divisé.* » [21] Cela demande du temps pour être considéré comme intrinsèque au mouvement, plutôt que juste une mesure externe. [22]

[15] Crang, 2001, p.206
[16] Gren, 2001, p211
[17] Ibid., p.209
[18] *'individual rhythms as rather unsensual and disembodied',* Mels in Tim Edensor, 2010, p.1
[19] 'place ourselves *inside the line of each trajectory* instead of observing them from the outside in relation to the coordinates of time and space signified in the diagram.', Gren, 2001, p.212
[20] *'movement (time) is different from distance covered which as a line may be infinitely divided (space)',* Deleuze (1991) in Crang, 2001, p.206
[21] *'cannot be divided without changing qualitatively each time it is divided* ', Deleuze (1986:1) in Crang, 2001, p.206
[22] Deleuze (1991) in Crang, 2001, p.207

Dans la recherche de la représentation d'un espace-temps plus dynamique, Deleuze cherche des «*représentations qui codent les forces et le mouvement du temps*». [23] Cependant, plutôt que de simplement lutter pour une représentation plus «réaliste», ce qui lui est nécessaire est la représentation de la corporéité à travers l'expérience d'une «*activité corporelle*» elle-même. [24]

Dans le domaine appliqué du design urbain, Bosselmann parlait aussi d'une «forme expérientielle de la représentation» vers une communication plus efficace des projets de design urbain:

«Peu de gens en dehors du domaine de la conception et de l'ingénierie peuvent lire des dessins bidimensionnels et de comprendre ce que ce serait comme de marcher à côté d'un bâtiment montré. Le grand public comprend la forme expérientielle de représentations. » [25]

En outre, il devait reconnaître le besoin de telles techniques de représentation pour l'utilisation de l'architecte ou de l'urbaniste dans le processus de conception lui-même.

«L'image mentale d'un design n'est que partiellement exprimée par ces graphiques. Conventions graphiques de moins en moins précises existent pour exprimer l'expérience des idées de design ». [26]

L'initiative récente de cartographie sonore a le potentiel pour «animer» une carte d'une manière plus incarnée que l'observation plus externalisée d'une animation visuelle. Dans le but de représenter l'environnement acoustique d'un lieu, en plus de ses qualités physiques, la dimension sonore ajoute également l'élément de temps. Ainsi, en plus de la représentation de l'environnement sonore, une carte sonore peut également être utilisée comme une technique de représentation spatio-temporelle en général. Dans la prochaine section, nous allons explorer comment le potentiel du son peut représenter le mouvement temporel dans la ligne graphique, s'adressant au même temps à la question de la corporalité et du «*caractère subjectif de l'objectivité*» dans les techniques de représentation spatio-temporelles actuelles. [27]

[23] *'representations that within them encode the forces and movement of time'*., Ibid., p.206
[24] Gren, 2001, p.212
[25] *'Few people outside the design and engineering field can read two-dimensional drawings and understand what it would be like to walk alongside a building thus shown. The general public understands the experiential form of representations.',* Bosselmann et al., 1993, p.10
[26] *'The mental image of a design is only partially expressed by such graphics. Fewer and less exact graphic conventions exist for expressing the experience of design ideas.'*, Bosselmann et al., 1993, p.10
[27] *' subjective character of objectivity'* , Gren, 2001, p.212

Partie 2 : Sonifier les Rythmes Urbains

Introduction

Dans cette deuxième partie, nous tentons de «capturer» les rythmes urbains identifiés dans la première partie. Nous explorons les questions liées à la technique de représentation urbaine actuelle du masterplan graphique : l'absence de temporalité, les problèmes de lisibilité, et la synthèse de plusieurs couches de données. Afin de répondre à ces questions, nous nous tournons vers le domaine temporel de la musique et sa technique de représentation graphique de la partition. En s'appuyant sur des parallèles précédemment identifiés entre la partition musicale et le plan architectural ou urbain, nous proposons le masterplan comme partition musicale graphique et ouverte.

Afin de «jouer» ce masterplan, nous utilisons la technique de communication audio de la sonification: la traduction systématique des données en sons, dans ce cas des données d'image. Nous développons l'outil «Masterplan Urbain Sonifié» (SUM)[28] de sonification d'image et de composition graphique assistée par ordinateur, permettant à la fois la représentation urbaine et son design. Surtout, il peut supporter la nature multidimensionnelle et spatio-temporelle du système urbain.

Ensuite, nous développons une stratégie de sonification, afin de traduire les paramètres graphiques du masterplan urbain en paramètres sonores. Nous explorons les différentes techniques de sonification existantes, vers la représentation sonore effective de l'environnement urbain. En utilisant diverses techniques de synthèse sonore, nous développons un ensemble d'«Instruments urbains» pour le « mapping » de chaque élément urbain d'intérêt : le transport, la forme urbaine, l'activité et le design urbain. Le « Code Sonore Urbain » résultant sera appliqué à notre cas d'étude de la ville de Paris dans la troisième partie.

[28] Développé en collaboration avec Dr.Mika Kuuskankare pendant un période de recherhce à l'Ircam, Paris

Chapter 5 : Vers un «Masterplan Urbain Sonifié»

« … pour capter un rythme on doit être capturé par lui. Il faut se laisser aller, lâcher prise, et s'abandonner à sa durée. Comme dans la musique ... il faut être à la fois dedans et dehors. »

Lefebvre[29]

Dans le domaine de la planification urbaine, qui nécessite de composer de nombreux flux urbains dans l'espace ainsi que dans le temps, une technique de représentation spatio-temporelle est nécessaire. En conception urbaine, qui cherche à composer l'expérience humaine, l'incarnation de la corporalité est également souhaitable. Comme il a été mentionné dans la section précédente, les techniques graphiques utilisées en architecture et en design urbain, ainsi que celles utilisées en géographie du temps, ont leurs limites phénoménologiques, ce qui soulève la question de savoir si la temporalité est «*résistante à la représentation*». [30]

En raison de sa nature intrinsèquement temporelle, le son est bien adapté à la représentation du rythme. En outre, il a le potentiel pour concilier le corporel avec le « mappable ». Comme observé par Lefebvre, afin de saisir le rythme, il faut «*se laisser aller... s'abandonner à sa durée.* » Toutefois, afin de l'analyser, une «*certaine extériorité permet à l'intellect analytique de fonctionner*». [31] La musique, comme suggéré par Lefebvre, permet d'être à la fois «à l'intérieur et à l'extérieur » d'un rythme, nous rendant à la fois participant et observateur. Nous proposons donc le son comme un medium adapté autant pour représenter le rythme, que pour en faire l'expérience corporelle.

Cette connexion entre la musique et l'expérience urbaine a été élaborée par un certain nombre d'architectes et d'urbanistes, à partir de l'analogie de Goethe de l'architecture comme «musique figée». Alors que la majeure partie de l'exploration avait mis l'accent sur l'objet architectural lui-même, l'architecte paysagiste Hanoch-Roe a proposé la partition musicale pour le «scoring» de l'expérience urbaine dans son ensemble, pour la création d'un design urbain plus «fluide».

Ainsi, nous explorons l'utilisation de la partition graphique pour la représentation de design urbain. Nous cherchons à traduire l'espace graphique du masterplan urbain dans l'espace temporel de la musique. Pour «jouer» le masterplan comme une partition musicale, et ainsi révéler ses rythmes, nous proposons l'utilisation du son. En particulier, nous proposons la technique de communication audio de «sonification» - la représentation des données par des moyens auditifs – pour le développement d'un plan d'urbanisme sonifié.

[29] *'to capture a rhythm one needs to have been captured by it. One has to let go, give and abandon oneself to its duration. Just as in music … one must be at the same time both inside and out.',* Lefebvre, 1995, p.219, in Crang, 2001, p.200

[30] Quick, 1998, p.65-6, in Crang, 2001, p.200

[31] Lefebvre, 1995, p.219, in Crang, 2001, p.27

Chapter 6 : Une strategie de sonification urbaine

Dans ce chapitre, nous examinons la technique de sonification plus en détail, avant de concevoir un outil soutenant la sonification du masterplan. Comme nous nous intéressons à l'utilisation de la sonification à des fins d'analyse et de design, nous sommes à la recherche d'un outil permettant la sonification d'images existantes ainsi que leur composition graphique.

Un processus de la sonification « urbaine »

Dans l'élaboration d'une stratégie de la sonification pour n'importe quelle application, l'approche la plus appropriée est la réunion de la fonction et de la technique. Dans notre objectif de sonifier le masterplan urbain, nous nous intéressons essentiellement à la traduction de l'image en son. Ainsi, nous allons d'abord utiliser une approche de «mapping» des paramètres pour traduire les paramètres graphiques en attributs audio, comme le montre la figure 6.2. Cela nous permettra de construire le masterplan comme une partition graphique sonifiée, lui permettant d'être joué d'une manière semblable à un instrument avec la sonification basée sur modèle.

Figure 6.1: Le processus de la sonification « urbaine »

Un outil de sonification d'image et de composition graphique

Afin de soutenir les multiples flux spatio-temporels du système urbain, nous avons besoin d'un outil permettant la définition de plusieurs trajets spatio-temporels.

En outre, afin de permettre à la fois l'analyse et la conception urbaine, l'outil doit supporter à la fois l'importation de multiples images raster et la création d'objets vectoriels. Un tel outil combine donc les fonctions de sonification d'image et de composition graphique.

L'élaboration et l'implémentation d'un tel outil de sonification et de composition multi-dimensionnelle seront décrites dans le chapitre suivant.

Chapter 7 : L'outil SUM

Après avoir discuté des outils existants de sonification d'image, nous présentons l'outil SUM « Masterplan Urbain Sonifié» qui associe les techniques de sonification d'image à une approche graphique de composition assistée par ordinateur pour la représentation et le design du système urbain.

Pour pouvoir prendre en charge les différents types de cartes utilisées dans le design et la planification urbaine, l'outil SUM vise à permettre aussi bien la superposition de multiples couches d'images que leurs synthèses. Il supportera à la fois les images raster et vectorielles, en proposant l'importation d'images existantes ainsi que la création de nouveaux dessins directement depuis l'interface.

Afin de représenter la multitude de flux spatio-temporels urbains, l'outil SUM permettra la coexistence de plusieurs trajets et une définition indépendante de leurs propriétés spatio-temporelles. Ces chemins seront utilisés pour récupérer les données à partir de plusieurs images pouvant ainsi être jouées comme des partitions graphiques ouvertes.

Grâce à cette approche spatio-temporelle multidimensionnelle, l'outil SUM espère fournir une structure commune pour la sonification d'image et la composition graphique assistée par ordinateur permettant à la fois la représentation de l'état actuel et le design futur du système urbain.

Nous avons choisi de réaliser l'outil SUM dans le cadre de l'environnement visuel de composition assistée par ordinateur PWGL qui est basé sur Lisp et largement répandu. Il offre la flexibilité nécessaire à une utilisation en tant qu'outil de sonification comme de composition graphique.

Ce chapitre examine la structure de SUM en termes de processus de sonification et de composition. Pour une utilisation personnelle, les liens suivants sont fournis :

- Le logiciel PWGL peut être téléchargé ici : http://www2.siba.fi/pwgl/downloads.html

- L'outil SUM, sous forme de librairie PWGL, peut être consulté ici : https://www.dropbox.com/s/4n0mhz7ifkqmnon/PWGL-SUM-software-v2-5.zip

- La documentation de l'outil SUM peut être consultée ici : https://www.dropbox.com/s/lo1xhj2cv69qluw/SUM_documentation.pdf

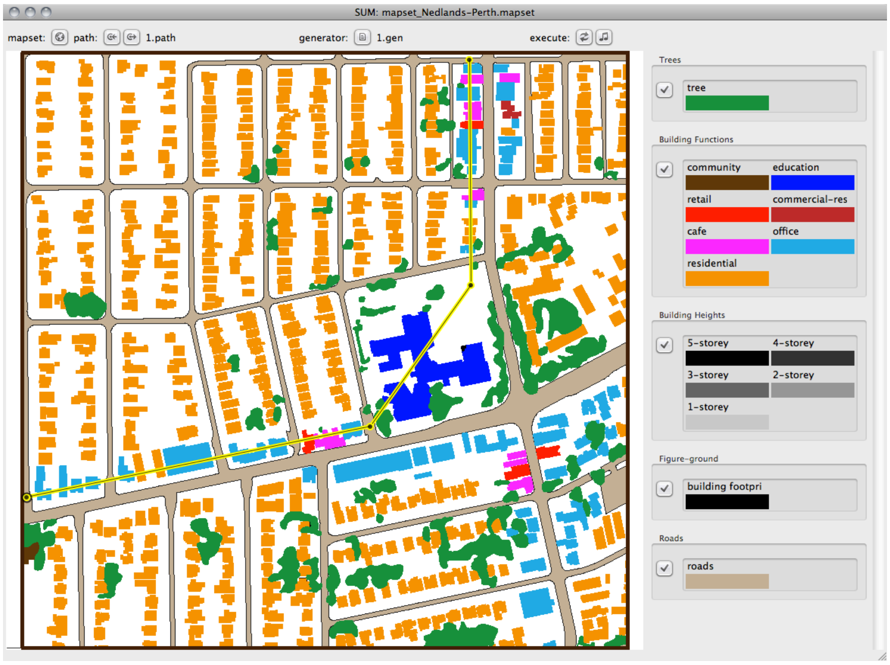


Figure 7.1: L'interface graphique de l'outil SUM, montrant une image raster de Perth

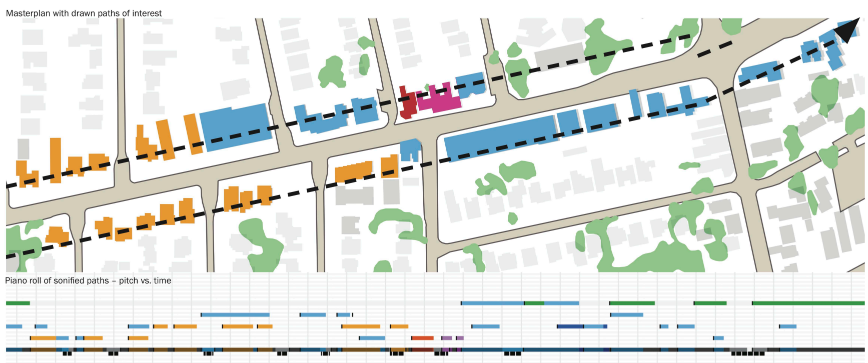


Figure 7.2: Le piano-roll résultant de la sonification de deux chemins à une vitesse donnée

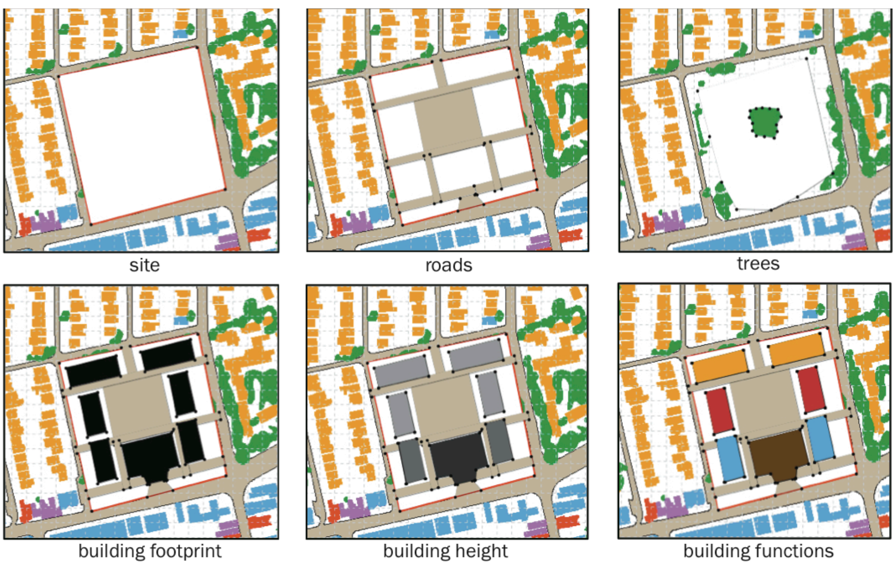


Figure 7.3: Redessiner une section de Perth en utilisant l'éditeur d'objets vectoriels

Chapter 8 : Le Design Sonore Urbain

Nous proposons une stratégie de design sonore pour la sonification des systèmes urbains précédemment identifiés : le transport, l'activité, la morphologie, le design, et l'environnement naturel. Après avoir étudié en détail les techniques existantes de sonification et leurs rôles dans la communication acoustique, nous développons une série des « instruments urbains », qui peuvent être contrôlés par l'outil SUM à l'aide d'un processus d'association (« mapping »).

La communication acoustique

Une communication acoustique efficace implique tout d'abord une compréhension de la façon dont nous entendons - musicalement, écologiquement, et sémantiquement. Sur cette base, nous pouvons mieux appréhender ce que nous entendons- les «objets sonores», les «sounding objects», les signes sémiotiques - et les dimensions sonores qui peuvent être utilisées pour les concevoir. Nous exposons donc dans cette section une stratégie de design sonore efficace pour la représentation de l'environnement urbain.

Comment nous entendons - *Ce que nous entendons*

Pour comprendre la façon dont nous percevons acoustiquement notre environnement urbain, nous explorons les différents modes d'écoute pratiqués dans différentes situations. Gaver a introduit le concept d'«écoute quotidienne», relative à la perception auditive de notre environnement sonore quotidien par opposition à «l'écoute musicale ». Pierre Schaeffer a proposé un nouveau mode d' « écoute réduite », qui sous-tend l'identification de nouveaux « objets sonores ». Nous expliquons ces deux modes d'écoute ci-dessous, ainsi que le concept de l'écoute sémantique.

Les techniques de représentation sonore

Nous explorons ensuite différentes approches de la communication acoustique et des techniques de représentations sonores actuellement utilisées. La représentation iconique apparaît être efficace lorsque l'information est physiquement liée aux sources sonores de référence, en exploitant les expériences physiques quotidiennes d'interprétation des sons. [32] Toutefois, si les données ne sont pas immédiatement associables avec des objets sonores, une représentation plus abstraite peut être nécessaire. Dans ce cas, les modèles musicaux fournissent une structure esthétique pour la représentation. Une approche rhétorique peut également faciliter la communication sémantique et son apprentissage. Chaque approche a ses avantages, et un design sonore efficace implique souvent un compromis entre précision, intuitivité et esthétique.[33]

[32] de Götzen, et.al., 2008, p.412
[33] Hermann, 2011, p.364

Un design sonore urbain

En s’appuyant sur l'étude de la communication acoustique efficace exposée précédemment, nous présentons une stratégie de design sonore pour l’association (« mapping ») de chaque source de données urbaines avec des paramètres audio. Dans la représentation sonore de chaque système urbain, nous utilisons les techniques de représentation iconique, abstraite et musicale précédemment explorées. Elles sont employées selon la nature de chacun des éléments envisagés : l'environnement naturel, la morphologie urbaine, les infrastructures de transport, la distribution de l'activité et les objets de design urbain. Ceci aboutit à un ensemble d’ «instruments urbains» pouvant être joués par SUM grâce à un « mapping » de chaque dataset urbain à des paramètres sonores.

Les instruments urbains de SUM

Dans ce but, nous avons développé cinq modèles de design sonore différents pour la représentation de chaque système urbain, que nous avons appelé « instruments urbains ».

i. ***L’instrument d’environnement***
   - pour la synthèse de l'environnement naturel et l’espace public ouvert
ii. ***L’instrument de transport***
   - pour la synthèse des infrastructures de transport public
iii. ***L’instrument d’activité***
   - pour la synthèse des activités intérieures
iv. ***L’instrument de la forme urbaine***
   - la représentation de la hauteur et de la longueur du bâtiment
v. ***L’instrument des objets de design urbain***
   - pour la synthèse d’outils de sonification

Proposition: Un orchestre urbain

Lorsqu'il est appliqué au système urbain dans son ensemble, chaque système peut être considéré comme une section isolée de l’orchestre, créant ainsi un « orchestre urbain » comme le résume le tableau 8.1.

Table 8.1: Relationship between each urban system and instrument

Urban System	Instrumental Section
Environment	Brass
Transportation	Strings
Urban Activities	Woodwind
Urban Form	Tuned Percussion
Urban Design	Percussion

L'implémentation des instruments

Les instruments ont été développés dans Max/MSP, un langage de programmation visuel couramment utilisé pour l'informatique musicale. Ils sont basés sur des principes de modélisation physique et utilisent les objets Modalys[34] développés par l'Ircam. Ils sont contrôlés par SUM à travers l'importation de paramètres audio (l'instrument, la hauteur, la vitesse, la durée, et l'articulation) par Open Sound Control (OSC)[35].

De plus amples détails au sujet de la mise en œuvre des instruments peuvent être trouvés dans l'annexe : *Instruments Urbains de SUM*. Ces instruments sont utilisés dans la troisième partie concernant la sonification de notre cas d'étude : la ville de Paris.

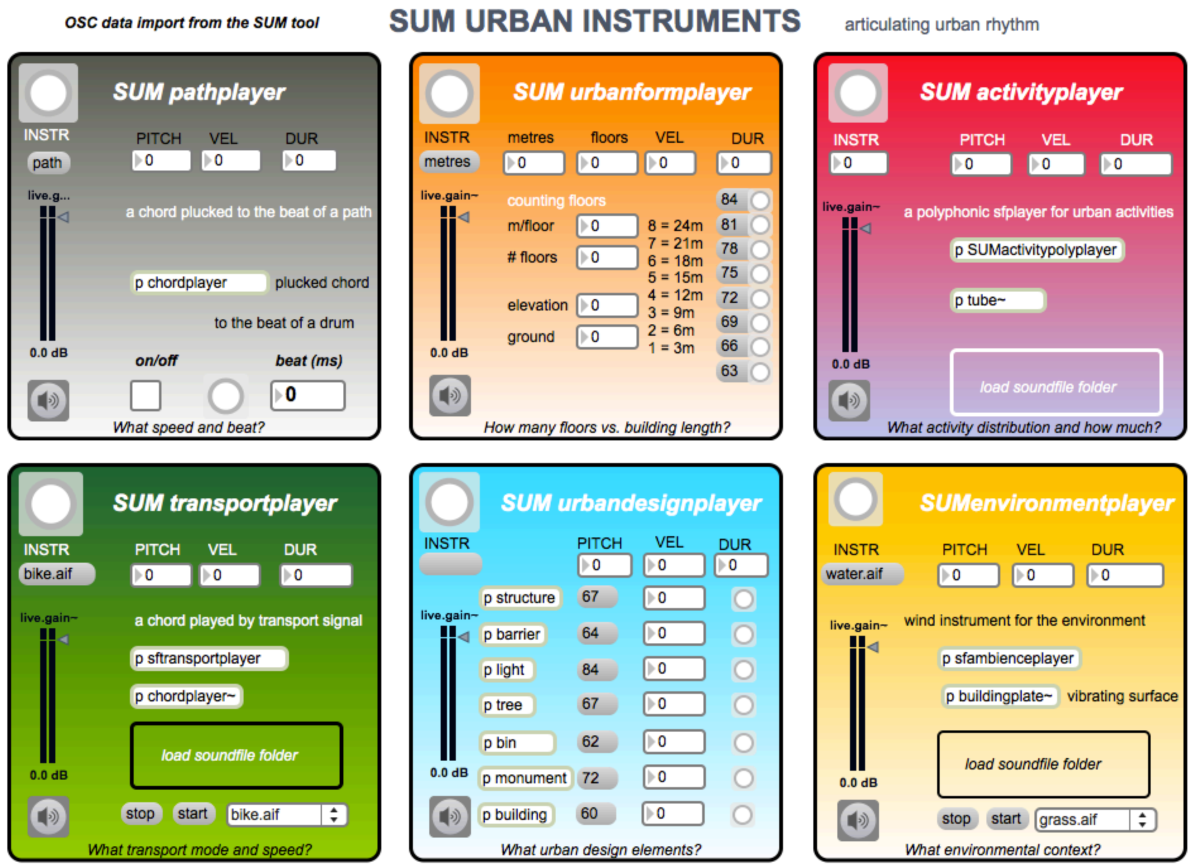


Figure 8.1: L'ensemble des 'Instruments Urbains' de SUM

Une vidéo de démonstration peut être consulté ici :

https://www.dropbox.com/s/ombpjyqw07k99u7/SUMpart2_UrbanSonicCode.mp4

[34] http://forumnet.ircam.fr/product/modalys/?lang=en
[35] http://cycling74.com/products/max/

Partie 3 : Écouter les Rythmes Urbains

Introduction

Dans cette troisième partie, nous explorons l'utilisation de l'outil SUM dans la représentation des rythmes urbains. Tout d'abord, nous appliquons notre stratégie de la sonification urbaine à notre cas d'étude de Paris, générant un ensemble de cartes urbaines sonifiées de la ville qui nous permettent d'écouter ces différents rythmes urbains. Nous utilisons l'outil de SUM pour sonifier les ensembles de données urbaines d'intérêt : le transport, la forme urbaine, l'activité, et le design urbain. Ensuite nous appliquons nos « Instruments Urbains » générés dans la deuxième partie pour synthétiser un code sonore urbain. Le résultat est un « Masterplan Urbain Sonifié » de Paris, ce qui nous permet d'écouter, de manière indépendante ou en combinaison, l'organisation spatio-temporelle de la ville. L'efficacité de la sonification est évaluée dans une enquête publique.

Ensuite, nous explorons l'utilisation de l'outil de SUM dans l'analyse de rythmes urbains quotidiens - vers une « Rythmanalyse sonifiée ». Notre objectif est de représenter les divers rythmes quotidiens de Paris, du point de vue de ses habitants. Ainsi, nous avons mené une enquête de cartographie dans laquelle les participants ont été invités à dessiner leurs déplacements spatio-temporels dans une journée typique. Nous reconnaissons quatre types de rythmes quotidiens : régionaux, périphériques, métropolitains, ainsi qu'intra-muros. Un exemple de chaque type rythmique a été sonifié et leur propriétaire invité à identifier leur chemin à l'oreille. Grâce à l'utilisation du son, nous explorons les possibilités et les contraintes temporelles offertes par la ville de Paris.

Chapter 9 : Masterplan Urbain Sonifié de Paris

Dans ce chapitre, nous appliquons l'outil SUM à notre cas d'étude de Paris, afin de générer une série de bases de données composées d'une carte représentant les éléments de chaque système urbain. Chaque ensemble d'images est alors sonifié à l'aide des instruments urbains précédemment développés, donnant lieu à un Masterplan Urbain Sonifié de Paris. Les systèmes urbains peuvent être écoutés individuellement ou ensemble. Jouée par les chemins d'intérêts, la composition le long de chaque chemin peut être entendue au fil du temps. Comme une étude comparative, nous sonifions le design urbain de plusieurs types de rue trouvés à Paris. Les différences dans leurs compositions spatio-temporelles peuvent être entendues. L'efficacité de notre sonification de Paris est ensuite évaluée par la consultation publique.

La sonification des rythmes de Paris

Nous présentons notre stratégie pour la sonification de chacun des systèmes urbains suivants de Paris et leurs paramètres urbains d'intérêt.

1. **L'Environnement naturel** - la Seine, les bois naturels et les parcs et jardins

2. **Les Infrastructures de transport** - l'infrastructure publique du rail régional et métropolitain, le réseau routier, les rues piétonnes et les pistes cyclables

3. **La Morphologie urbaine** - la forme des bâtiments – la position, la longueur et la hauteur

4. **Les Activités publiques** – les différents types de services publics fournis par la ville de Paris, dont : la communauté, le divertissement, l'éducation, la santé, le bureau, le sport, le commerce

5. **Les Éléments de design urbain** - la structure du bâtiment, les barrières, les lumières, les poubelles, les arbres et les monuments.

La sonification des rues de Paris

Nous allons à présent sonifier l'ensemble des données de design urbain le long des trois types principaux de rues trouvés à Paris, afin de comparer l'organisation de leurs éléments urbains :

I. Boulevards
II. Avenues
III. Rues

Chacun de ces types de rue est conçu pour supporter différents flux de transport. Leur sonification permet à leur composition d'être entendue à leurs vitesses de mouvement respectives.

Ecouter les rues de Paris

De ces trois sonifications de différents types de rue à Paris, nous pouvons entendre les différences rythmiques dans leur design urbain à leurs vitesses respectives de voyage. Des comparaisons similaires peuvent être faites pour chaque système d'activité urbaine : transport, forme et ambiance. Tous peuvent être combinés en fonction de la structure compositionnelle « partition SUM » de la figure 9.1, afin d'écouter la composition rythmique de l'ensemble de la rue.

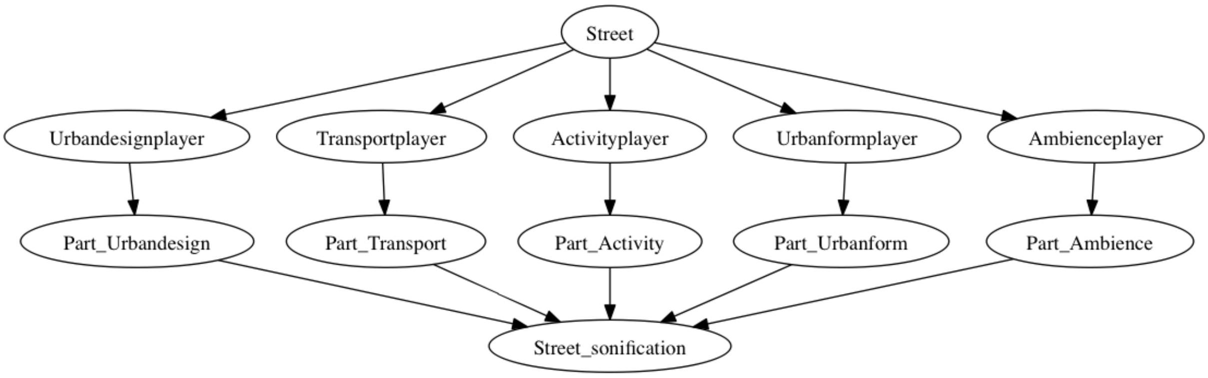


Figure 9.1: La structure compositionnelle pour la sonification de l'ensemble d'une rue

Nous appliquons cette « partition SUM » au boulevard de Sébastopol afin d'entendre sa composition urbaine globale.

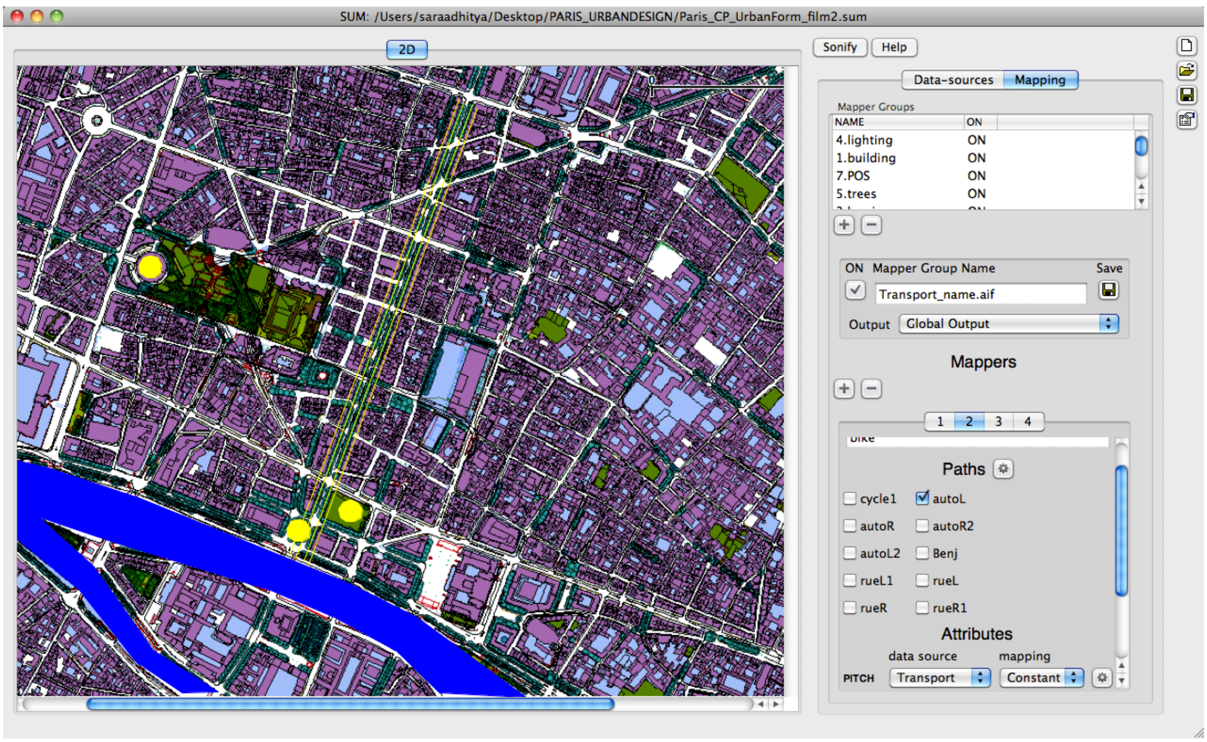


Figure 9.2: La sonification de Boulevard de Sébastopol, Chatelet

Enquête publique : Ecouter Paris

Dans cette section, nous évaluons l'efficacité de l'outil SUM et notre « Code Sonore Urbain » appliqué à Paris. Un questionnaire ouvert a été réalisé et dans lequel nous avons demandé au grand public (excluant les professionnels de l'urbanisme) de réfléchir à leur expérience du « Masterplan Urbain Sonifié » de Paris tel qu'il est présenté dans la vidéo suivante:

https://www.dropbox.com/s/wem2p02atb0l4g9/SUM_VIDEO_send.mp4

Les 25 réponses sont discutées ci-dessous et sont amplement détaillées dans l'Annexe 4: Questionnaires & Expériences (Questionnaire 1).

L'utilisation de SUM pour la représentation urbaine

'Listening to the transposition in sound of the monuments, offices, markets, trees of Boulevard Sebastopol opened me up to the possibility that this manner of interpreting the urban dimension may in fact help to develop a deeper understanding of the city in which I live.'

La réponse initiale au « Masterplan Urbain Sonifié » de Paris démontre le potentiel de SUM comme outil de représentation urbaine. La variété de réactions évoquées - émotionnelle, esthétique et intellectuelle - démontre la puissance du son pour communiquer à un certain nombre de niveaux. Les sujets ont confirmé la capacité de la sonification à représenter le mouvement urbain, l'expérience, le rythme et la «vie» en général. En outre, nombreux y ont trouvé une nouvelle approche pour comprendre la ville à travers l'écoute, à la fois du paysage sonore et de leurs expériences corporelles. La dimension sonore a également aidé à communiquer la pluralité de la ville souvent enfouie dans le plan graphique, permettant de comprendre la relation entre les différents systèmes urbains, ainsi que leurs places dans la «toile rythmique» dans laquelle ils vivent et bougent. Une formation complémentaire au code sonore permettrait l'avancement de la sonification comme une technique de représentation urbaine. Enfin, la variété de suggestions pour les applications de SUM dans l'avenir indique un désir d'en apprendre plus sur et d'interagir avec.

Chapter 10 : Rythmanalyse Urbaine Sonifiée

Dans ce chapitre, nous appliquons l'outil SUM à la sonification des différents rythmes quotidiens à Paris. Cela nous permet d'identifier les différents rythmes quotidiens soutenus par la structure urbaine de Paris, vers le développement d'une «Rythmanalyse Urbaine Sonifiée».

Exercice 1 : Les Rythmes Urbains Quotidiens de Paris

Tout d'abord, un exercice a été réalisé dans lequel des sujets divers vivant et / ou travaillant à Paris ont été invités à dessiner le chemin de leur journée typique (de et vers la maison). Ils ont été invités à indiquer les destinations d'activité principales (maison, travail, magasin, bar, théâtre, etc.) et leur itinéraire choisi, y compris le mode de transport (bus, à pied, en métro, RER, etc.) Ils ont également été invités à préciser l'heure (par exemple, 09:00, 21:00), ce qui nous a permis de comprendre la distribution de leur activité pendant la journée.

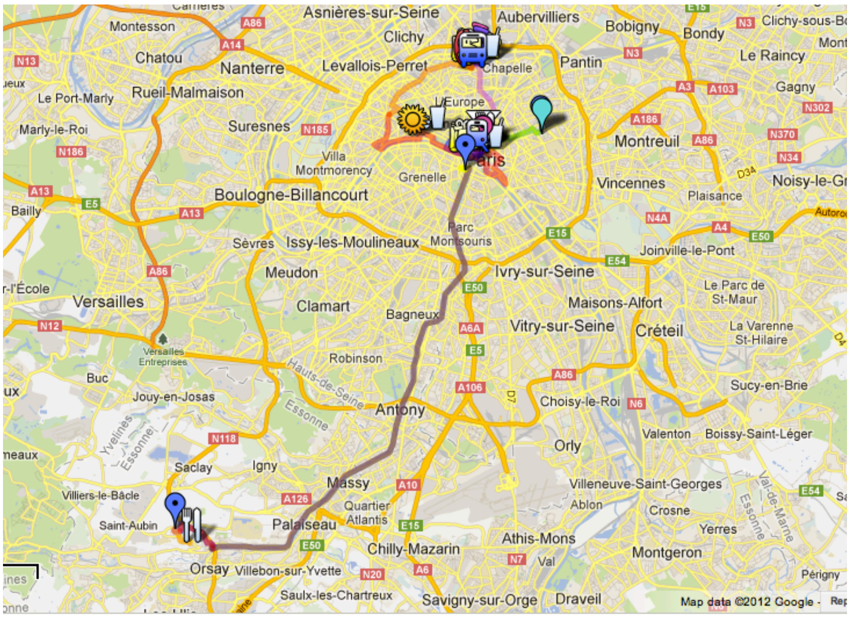


Figure 10.1: La cartographie des chemins quotidiens d'espace-temps dessinés dans Googlemaps

Quatre types de rythmes quotidiens ont été identifiés, selon les lieux de résidence et de travail des huit sujets :

1. régional
2. périphérique
3. métropolitain
4. centre-ville

Exercice 2 : L'apprentissage du Code Sonore Urbain

Ensuite, le « Code Sonore Urbain» a été expliqué aux participants. Ceux-ci ont été divisés en trois groupes de sons : le transport, l'activité, et l'ambiance. Chaque son dure 3 à 5 secondes. Un bref exercice d'écoute impliquant l'identification des sons joués a été utilisé pour faciliter l'apprentissage des sons ainsi que pour tester la compréhension du code. Après une seule écoute du « Code Sonore Urbain » (où chaque son est répété deux fois), tous les participants ont identifié au moins 5 des 6 sons correctement. Voir Annexe 4 : Questionnaires & Expériences (Exercice d'écoute 1) pour plus de détails concernant l'expérience.

Exercice 3 : Les Rythmes « Urbains Quotidiens Sonifiés » (SDU)

Dans la troisième partie de la Rythmanalyse, les participants ont écouté leurs rythmes quotidiens, en fonction de leurs mouvements urbains dessinés précédemment.

Le rythme quotidien de chaque participant a été sonifié selon le « Code Sonore Urbain », en réduisant leur journée proportionnellement dans le temps. Ainsi, une heure est représentée par 4 secondes (soit 15 min / sec), une journée normale faisant ainsi moins d' 1 minute. Seuls les événements principaux de la journée (i.e. le transport et les activités primaires) ont été sonifiés.

Après avoir écouté leur propre rythme « Urbain Quotidien Sonifié » (SDU), sans l'aide visuelle de leur carte, les participants ont ensuite été invités à répondre à plusieurs questions concernant leur expérience d'écoute.

A travers cet exercice de Rythmanalyse sonifiée, nous pouvons voir comment la sonification de son rythme urbain quotidien a suscité une réflexion de chaque sujet sur son propre rythme urbain, ses infrastructures et son mode de vie. Il a également suscité la curiosité dans les rythmes des autres : *«Je serais plus intéressé à écouter le rythme urbain quotidien de quelqu'un d'autre.*" (FT) Cet aspect comparatif offert par la sonification sera exploré dans la section suivante, qui implique l'identification de son propre rythme SDU parmi ceux des autres participants.

Exercice 4 : La Reconnaissance de Rythme SDU

Dans la troisième et dernière partie de cette expérience d'écoute, nous étudions la capacité des sujets à reconnaître leurs rythmes urbains quotidiens sonifiés. Nous avons réalisé une expérience simple dans laquelle on a demandé aux participants d'identifier leurs rythmes urbains quotidiens sonifiés parmi un groupe de trois rythmes SDU. Le but de l'exercice était de comprendre la facilité ou difficulté d'identifier son rythme et aussi de comprendre l'effet comparatif d'écouter d'autres rythmes.

Discussion : Vers une Rythmanalyse Urbaine Sonifiée

Ces premières expériences ont montré que la sonification peut être un moyen efficace de représenter son rythme quotidien urbain, avec presque un taux de réussite de 100% lors de l'identification correcte du code sonore initial. Tous les participants ont en effet facilement reconnu leur rythme. Cela peut être attribué à l'efficacité de sons iconiques, et potentiellement à leur incarnation dans le rythme.

En outre, les commentaires des participants concernant leurs rythmes quotidiens étaient cohérents avec leur exercice initial de cartographie. Par exemple, ceux insatisfaits de leur temps de déplacement étaient toujours insatisfaits après l'écoute. Cependant, le son était capable de mieux faire apparaître les proportions exactes du temps passé dans les trajets ou de travail, suscitant des commentaires tels que «Je fais trop la navette» et «Je travaille trop».

Dans le même temps, la capacité de la sonification à communiquer les rythmes des autres a provoqué des réactions concernant la variété des activités le long de la journée, avec ceux qui ont un certain nombre d'activités enviés par ceux qui ont travaillé de façon monotone durant 6 ou 7 heures d'affilée. À partir à la fois de l'expérience d'écoute initiale et des changements provoqués en raison de l'écoute comparative, on peut voir que la sonification a la capacité d'aider à la compréhension de ses propres rythmes ainsi que de ceux des autres.

Avec d'autres améliorations du code sonore, la sonification du rythme montre un grand potentiel dans le développement de la technique de Rythmanalyse comme une «science analytique» telle qu'initialement proposée par Lefebvre.

Partie 4 : Le Design de Rythmes Urbains

Introduction

Dans cette quatrième partie, nous explorons le 'design' de rythmes urbains. Nous proposons l'utilisation de structures musicales pour composer l'expérience urbaine. S'appuyant sur des parallèles précédemment identifiés entre la partition musicale et le plan architectural ou urbain, nous continuons notre exploration du masterplan comme une partition musicale ouverte et graphique. Cependant, cette fois, nous inversons le processus, générant les graphiques à partir des sons, plutôt que le son à partir des graphiques.

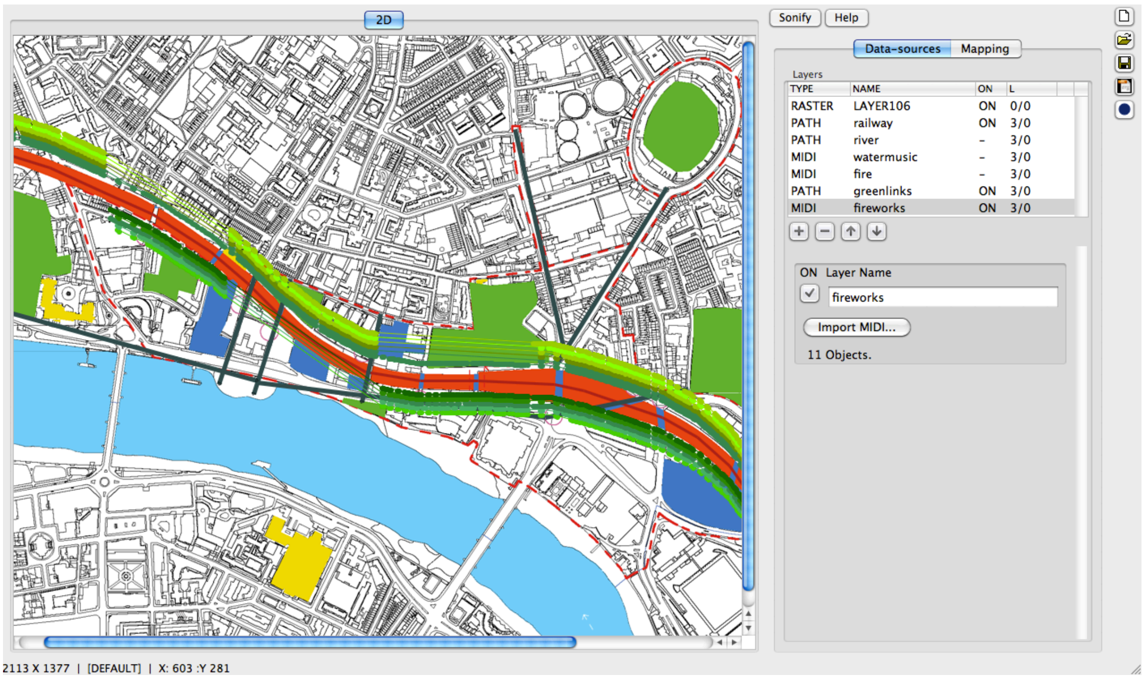


Figure 11.1: L'utilisation de structures musicales pour composer l'expérience urbaine en SUM

Chapter 11 : SUM Comme Outil de Design

Afin d'explorer son potentiel, nous utilisons SUM comme un outil de design pour un projet de design urbain actuel, intitulé « *Vauxhall: The Missing Link, an 'Urban Design, Landscape, Architecture and Public Realm competition* ». [36] L'objectif de cet appel ouvert à été de reconnecter les parties déconnectés du quartier par «*un chemin identifiable et narratif à travers la région, reliant les arches du chemin de fer, les espaces verts et l'art public dans un lieu distinctif de nouveau* ».[37]

Enfin de composer cette « connexion perdue », nous générons des rythmes urbains à partir des rythmes musicaux. En hommage à l'histoire du site sur la rive sud de Londres, premier lieu de performance de la suite orchestrale de «*Music for the Royal Fireworks*» en D, HWV351, de Handel, et aussi de son « *Water Music* ». En particulier, nous avons choisi d'utiliser le mouvement '*La Réjouissance*', et la suite No.2 en D de « *Water Music* », HWV349, comme générateur du design.

En collaboration avec l'architecte et designer urbain Jennifer Scott, nous explorons l'utilisation de SUM comme un outil de design et comment la musique peut être utilisée pour informer la composition de l'expérience urbaine. Nous avons développé un projet urbain - un parc urbain pour le réaménagement de Vauxhall. Ce projet a été exposé à Vauxhall et à Londres en avril 2013 au Museum du Jardin.

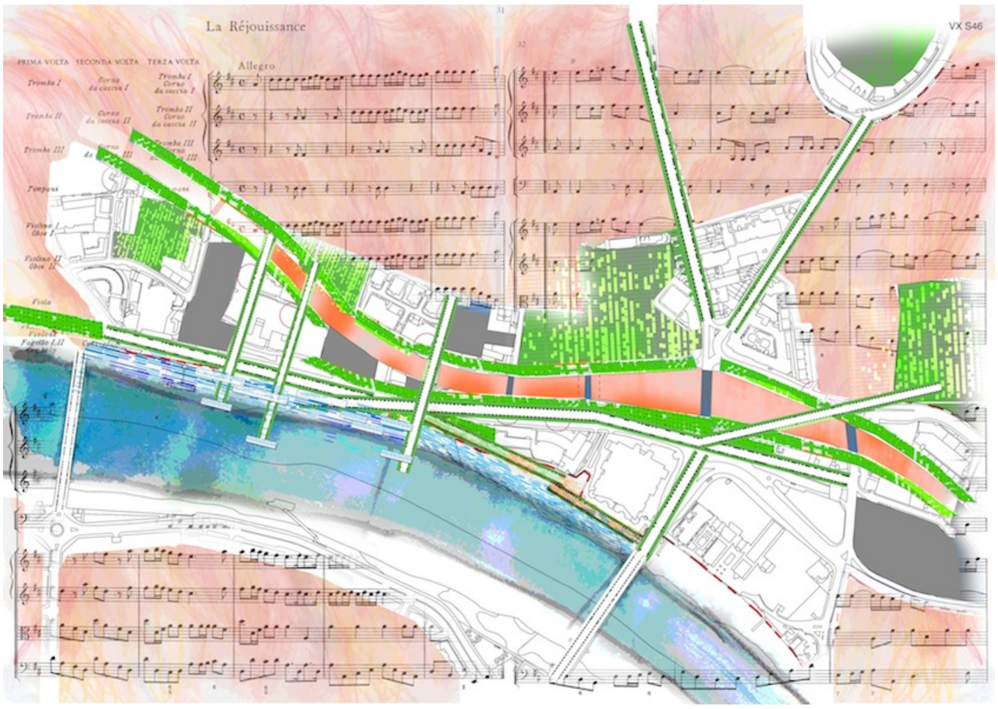


Figure 11.2: Le projet urbain proposé pour Vauxhall, Londres

[36] http://www.ribacompetitions.com/vauxhallthemissinglink/brief.html [Accessed February 2013]
[37] ibid. '*an identifiable pathway and narrative through the area, linking the railway arches, green spaces and public art into a distinctive place once again*'.

Chapter 12 : Enquête professionnel

Enfin, on a consulté les professionnels d'urbanisme, dont les architectes, urbanistes, planificateurs et ingénieurs, concernant le potentiel de l'outil SUM pour la conception et la planification urbaine. Les commentaires de six professionnels urbains à travers le monde (Italie, France et Australie) sont discutés:

i. Architecte, Paris, France
ii. Planificateur et Ingénieur, Perth, Australie
iii. Architecte, Trévise, Italie
iv. Urban Designer, Perth, Australie
v. Architecte, Forli, Italie
vi. Architecte, Paris, France

Leurs commentaires individuels sont disponibles en détail dans l'Annexe 4 : Questionnaires & Expériences (Questionnaire 3).

L'avenir de SUM pour la conception et la planification urbaine

La grande variété des réponses et les idées reçues par SUM jusqu'ici, le potentiel de son application dans le design et la planification urbaine est riche. Comme noté par le planificateur, *«... Je vois bien un avenir où le son est intégré dans la planification / conception urbaine»* [38]. Quelle direction prendra SUM - comme un outil de représentation, de conception, ou d'analyse – cela dépendra en grande partie de la direction des professionnels de design et de la planification urbaine choisiront de prendre.

[38] Planificateur et Ingénieur, Perth, Australie

Conclusions

Dans cette thèse, nous avons exploré le concept de rythmes urbains grâce à l'utilisation de la sonification. Après avoir examiné les différents types de rythmes qui existent dans la ville, nous avons cherché à les «capturer», comme proposé par Lefebvre. Nous avons imaginé un outil qui nous permettrait de concevoir à la fois dans le temps et dans l'espace, vers la composition spatio-temporelle de l'environnement urbain. À cette fin, nous avons proposé la création d'un « Masterplan Urbain Sonifié », un outil pour la sonification de plans d'urbanisme existants ainsi que pour la composition de nouveaux.

Les contributions de SUM

L'intégration de la sonification dans la conception urbaine et de la planification nous a permis de représenter, d'analyser, ainsi que de composer des rythmes urbains. Le développement d'un outil de sonification d'images nous a permis de traduire l'information graphique dans le domaine sonore. Son intégration dans un environnement de composition assistée par ordinateur graphique nous a permis de dessiner et de composer les sons dans l'espace.

Un outil de représentation

L'outil SUM a prouvé sa valeur comme un outil de représentation à travers la création d'un « Masterplan Urbain Sonifié » de Paris. Les rythmes urbains intégrés dans cette ville étaient représentés d'une manière qui ne peuvent être exprimés par un plan simplement graphique. L'efficacité de la sonification a été testée par une enquête publique et de nombreuses réponses positives ont été reçues. (Voir Annexe 4 : Questionnaires et Expériences)

Un outil d'analyse

Nous avons ensuite appliqué SUM à l'analyse des rythmes urbains quotidiens. Une étude des liens spatio-temporels a été réalisée afin d'identifier des rythmes urbains spécifiques dans la ville de Paris. Nous avons exploré si la sonification pouvait aider la compréhension de ces rythmes quotidiens et de leur expérience. Nous avons également testé le caractère reconnaissable de ces rythmes individuels par leurs propriétaires.

Ces résultats préliminaires sont prometteurs. Tous les participants ont été en mesure de reconnaître leurs rythmes. La sonification leur a permis de mieux comprendre la composition de leur vie quotidienne et les effets de la structure urbaine sur leurs rythmes urbains. Nous espérons développer cette méthodologie d'une « Rythmanalyse sonifiée», avec l'hypothèse qu'une meilleure compréhension de nos choix urbains quotidiens nous permettrait de mieux contrôler le temps de nos vies.

L'outil SUM peut donc être utilisé pour nous aider à répondre à des questions relatives à la composition spatio-temporelle de notre ville :

- La diversité et la densité - Où se loger ?
- L'activité et la sociabilité - Où sortir ?
- L'accessibilité et la connectivité - Comment s'y rendre ?
- L'expérience piétonne - Quel chemin prendre ?

À long terme, nous espérons que cette prise de conscience accrue des rythmes urbains contribuera aux décisions et aux réalisations relatives au milieu urbain ainsi qu'à l'amélioration de la qualité temporelle du design urbain.

Un outil de conception

Nous avons ensuite exploré l'utilisation de SUM comme un outil de conception, orienté sur la conception spatio-temporelle de l'environnement urbain. Nous avons cherché à améliorer la qualité temporelle de l'espace urbain par la structuration du mouvement au sein de cet espace d'après le rythme d'un morceau de musique. L'outil SUM nous a permis de concevoir dans le temps, tout comme dans la composition d'une partition musicale.

Un outil musical

Enfin, nous reconnaissons le potentiel «musical» de ce type de sonification et l'utilisation de l'outil de SUM dans le domaine de la composition musicale. Bien qu'en dehors des limites de cette thèse, nous avons étudié l'utilisation de cet outil dans la composition musicale en parallèle. Nous avons sonifié la «musique visuelle» des artistes tels que Paul Klee et Wassily Kandinsky et Piet Mondrian. Etant développé au sein de l'environnement de composition assistée par ordinateur de PWGL, l'outil SUM est bien adapté à la composition musicale. Nous avons également recréé des partitions graphiques multicouches et nous les avons jouées de différentes manières. Plus de détails peuvent être trouvés dans la section des publications de l'annexe. Toutefois, les possibilités d'un outil multidimensionnel et spatio-temporel tel que celui-ci nécessitent de nombreuses explorations artistiques.

Les applications futures

Dans le futur, l'outil SUM peut également être utile pour la représentation et conception audio-visuelle dans les domaines liés suivants, ainsi que pour la représentation d'autres systèmes complexes :

- La géographie du temps : La cartographie d'espace-temps.
- Les études de paysages sonores : La (re)composition d'environnement sonore.
- La phénoménologie : La représentation d'expérience rythmique corporelle.
- La planification de trafic : La modélisation de réseaux de transport existants ou futurs.
- La dynamique urbaine : La modélisation des systèmes urbains.

En conclusion, l'intégration de la sonification dans la conception et la planification urbaine a ouvert de nombreuses possibilités intéressantes pour des explorations futures.

Fin de Résumé Français
End of French Resume

Acknowledgements

Like a symphony brought to life by each musician
The following people helped this thesis to fruition :

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and the John Crampton trustees, for funding my proposition

But the music would not last without its kind listeners
And neither would the author without her kind friends
To all of you out there I send my heartfelt thanks
For your support and friendship until the very end…

Preface

Towards a Sonified Rhythmanalysis

Twenty years ago, French philosopher Henri Lefebvre (1901-1991) presented a theory and practice of *Rhythmanalysis*: the understanding of one's environment through the experience of its rhythms. By using the internal rhythms of one's body as a measure, one could then begin to analyse those of the urban environment. *Rhythmanalysis*[39], published in 1992, was to become his first and final book focusing on the subject.

This thesis hopes to develop Lefebvre's proposal of an 'analytical science' of rhythm through the use of sound, and in particular the technique of sonification. We aim to develop a *'Sonified Rhythmanalysis'*, allowing both urban professionals and the public alike to 'listen to the city'. In doing so, we hope to be able to compose more sustainable urban rhythms, through the design of the urban environment, as well as the daily choices we make.

'Rhythms: music of the city,
a picture which listens to itself,
image in the presence of a continuous sum.'

Lefebvre

[39] First published as: *Éléments de rythmanalyse,* Paris: Éditions Syllepse, 1992.
Later translated in English as : *Rhythmanalysis: Space, Time and Everyday Life*. London: Continuum, 2004.

Thesis Structure

In its development of a sonified Rhythmanalysis, this thesis is structured in 4 main parts:

Part 1: Theory

We identify the rhythms relevant to urban design and planning, exploring how urban rhythms have been represented, analysed and organised in related fields: Philosophy; Time-Geography; and Soundscape Studies.

Part 2: Methodology

We attempt to 'capture' these identified urban rhythms with sound and the technique of sonification. We develop a urban sonification strategy involving the creation of a Sonified Urban Masterplan (SUM) tool capable of sonifying existing images as well as graphically composing new ones.

Part 3: Applications

Representation: First, we apply the SUM tool to our case-study city of Paris, producing a sonified set of maps which can be listened to. We compare various parts of the city in terms of their various urban elements: transport infrastructure; activity; urban form and design.

Rhythmanalysis: Second, we explore the potential of a 'sonified' Rhythmanalysis by sonifying the everyday rhythms of a group of participants in Paris and then assessing the effectiveness of such a technique.

Part 4: Design

Finally, we explore the use of the SUM tool in urban design, generating visual structures from musical rhythms. We apply it to a current urban regeneration competition for London. We then consult urban professionals on their views regarding the application of the SUM tool in their future urban design and planning.

Thesis Components

Due to its multidisciplinary nature, this thesis manifests itself in 8 different forms:

A. This theoretical volume exploring the concept of urban rhythm
B. A software for image sonification and graphical computer-aided composition
C. A set of 'urban instruments' for the sonification of each urban dataset
D. A video introducing the urban sonic code and how one can 'play' the city
E. A collection of audio-visual sonifications of various urban elements
F. A 'Sonified Rhythmanalysis' of typical everyday rhythms in Paris
G. Surveyed responses from users, designers and the general public
H. An urban design project generated by different musical rhythms

Contents

Part 2: Sonifying Urban Rhythms

Part 3: Listening to Urban Rhythms

Part 4: Designing Urban Rhythms

List of Publications

(included in Appendix 6)

1. S. Adhitya and M. Kuuskankare, "The Sonified Urban Masterplan (SUM) Tool: Sonification For Urban Planning And Design," in Proceedings of the 17th International Conference on Auditory Display (ICAD 2011), Budapest, 2011

2. S. Adhitya, *Audio-assisted Visualization – Sonification of Complex Urban Systems with the SUM tool*, International Meeting on Visualization in Complex Environments, ASSYST- FuturICT Workshop, Torino, 17-18 Nov 2011, published online by Complex Systems Society Young Researchers Committee (CSS YoCo) : http://www.cssociety.org/YoCo

3. S. Adhitya and M. Kuuskankare, “SUM: de la sonification d’image à la composition graphique assistée par ordinateur,” in Actes des Journées d’Informatique Musicale (JIM 2012), Mons, Belgique, 2012, pp. 89-94.

4. S. Adhitya and M. Kuuskankare, "SUM: From Image-Based Sonification to Computer-Aided Composition," in Proceedings of the 9th International Symposium on Computer Music Modelling and Retrieval (CMMR 2012), London, United Kingdom, 2012, pp. 94-101.

5. S. Adhitya and M. Kuuskankare, "Composing Graphic Scores and Sonifying Visual Music with the SUM Tool," in Proceedings of the 9th Sound and Music Computing Conference (SMC 2012), Copenhagen, 2012, pp.171-175

6. M. Kuuskankare and S. Adhitya, “The Sum Tool As A Visual Controller For Image-Based Sound Synthesis”, In: 38th International Computer Music Conference (ICMC 2012), Ljubljana, Slovenia, 2012

7. S. Adhitya and M. Kuuskankare, “From Musical Score to Graphic Plan : The Development of SUM as a Design Tool”, In: 39th International Computer Music Conference (ICMC 2013), Perth, Western Australia, 2013

Introduction

Towards the spatio-temporal composition of the urban environment

This thesis identifies rhythm as an important quality of our urban environments. Defined as the interaction of a space, a time, and an energy (Lefebvre, 1992), urban rhythms exist in various forms: the natural environment; built form; transportation; activity; and urban design. The city is a composition of these rhythms at various spatial scales (from regional to local) as well as temporal scales (from yearly rhythms to everyday life). Urban life is a rhythmic experience and urban rhythms can thus be used as an indicator of the spatio-temporal quality of the urban environment.

In defining the rhythmic qualities of the urban environment, we look to the fields of Time-Geography, Rhythmanalysis philosophy and Soundscape Studies. While time-geographers proposed the objective mapping of spatio-temporal urban flows, French philosopher Henri Lefebvre[40] turned our attention inward to its phenomenological experience, and acoustic ecologists advised us to literally listen to the world around us.

However, in the spatial practice of urban design and planning, temporality can be difficult to capture. Temporal representation is limited in the graphic urban masterplan. Thus we propose the temporal medium of sound, and in particular the technique of sonification – the representation of data through auditory means[41] - in order to articulate its rhythms.

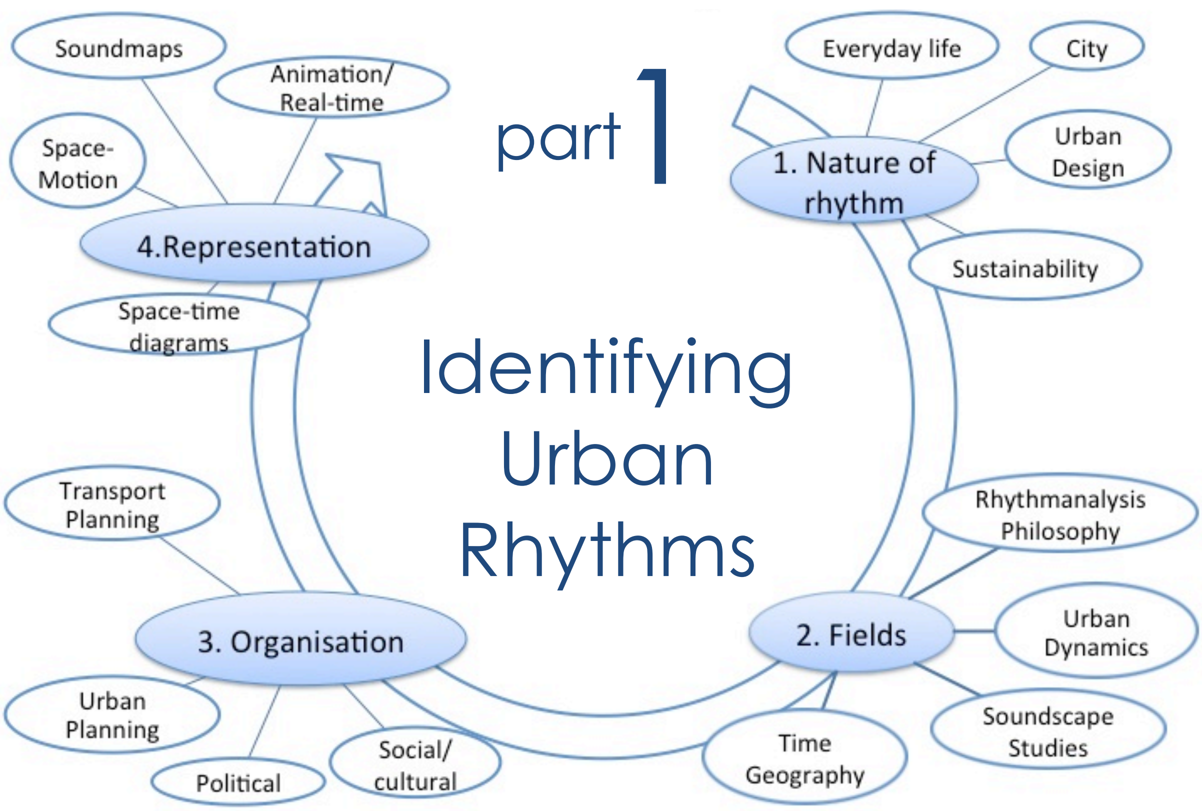
We seek to integrate rhythm into the urban design and planning process through the development of a *'Sonified Urban Masterplan'*, a tool for sonifying existing maps (through the importation of raster images) as well as graphically composing new ones (through the creation of vector objects). With the aid of an urban sonic code, we can translate the graphic urban elements of interest into sound, and thus articulate their composition in time as well as space.

Through this process of sonification, we aim to create a means of representing the temporal effects of our existing urban environment, revealing current urban rhythmic issues. At the same time, we provide the means for urban designers to graphically compose new rhythms, with the aim to improve the temporal quality of future urban designs. While the effects of a more rhythmic approach to urban design can only be revealed with time, the ability to represent these rhythms is a step forward in allowing us to take control of time and compose our everyday lives.

As realised by Lefebvre:

> *"… the city will only be rethought and reconstructed on its current ruins when we have properly understood that the city is the deployment of time."*[42]

[40] First published as: *Éléments de rythmanalyse,* Paris: Éditions Syllepse, 1992.
Later translated in English as : *Rhythmanalysis: Space, Time and Everyday Life*. London: Continuum, 2004.
[41] Kramer, G. (ed.), *Auditory Display – Sonification, Audification and Auditory Interfaces*, Addison Wesley, 1994
[42] Lefebvre H., *Writings on Cities*, in Kofman, E. and Lebas, E. (trans.), Basil Blackwell, Oxford, 1995: 16



Introduction

The first part of this thesis asks the fundamental questions: what is an urban rhythm; and why are they important to the quality of urban design?

We discuss the nature of rhythm and the types of rhythms relevant to our urban environments. We explore their relevance to sustainability and why we may want to 'recompose' these rhythms.

In order to explain this, we explore the various fields in which rhythm has previously been studied in relation to the urban environment: Time Geography; Philosophy; and Soundscape Studies.

We discover that there have been various attempts to develop a theory of Rhythmanalysis, most notably by French philosopher Henri Lefebvre, who proposed the development of an 'analytical science' of rhythms, shortly before his death in 1991.

Thus, we propose a continuation Lefebvre's research by exploring the various ways in which rhythms are currently organised in the city and how they are represented. We arrive at the question: how can we capture and represent these urban rhythms in order to analyse and thus compose them?

1 Introducing Urban Rhythms

Rhythm is an integral component of a number of disciplines and for this reason has attracted a number of definitions. The Oxford dictionary defines it as *'a strong, regular repeated pattern of movement or sound… a regularly recurring sequence of events or processes.*[43] It is most often referred to in music, poetry and dance, all clearly dependent on time as a means of expression. However, it has also been explored by visual artists such as Klee and Kandinsky, who aimed to represent rhythm graphically on the 2D canvas.

Philosopher Gilles Deleuze was to identify rhythm as something much larger than either its audio or visual representations: *'a vital power that exceeds every domain and traverses them all… more profound than vision, hearing, etc. Rhythm appears as music when it invests the visual level. This is a "logic of the senses," as Cézanne said, which is neither rational nor cerebral. What is ultimate is thus the relation between sensation and rhythm, which places in each sensation the levels and domain through which it passes.*'[44]

This 'power' of rhythm has been harnessed by a number of other disciplines, from psychology and psychoanalysis, to urban geography and acoustic ecology. In fact, there have been several attempts towards a theory of rhythms as a '*means of interpreting time and space'*.[45] In this chapter we will explore how a study of rhythm can aid urban designers and planners in the understanding of the spatio-temporal composition of our urban environments.

1.1 The Nature of Rhythm

In order to identify it with respect to our urban environments, we first define what constitutes rhythm. There has been a general consensus, whether in art, philosophy or geography, that rhythm is the result of two types of repetitions. Time-geographer Justin Winkler identifies rhythm as the *'approximate repetition of a cycle'*, as opposed to measure, '*the precise, identical repetition of a cycle; and frequency'*.[46] Klee explained the graphic generation of rhythm in his paintings through the juxtaposition of a regular 'élément dividuel' and a less regular 'élément individuel'.[47] Deleuze was to similarly identify these two types of repetitions, referring to the former as 'répétition-mesure' and the latter as 'répétition-rythme'.[48] Thus rhythm implies repetition, yet it does not exclude difference. In

[43] http://oxforddictionaries.com/definition/english/rhythm [accessed 31 January 2012]
[44] Deleuze, *Francis Bacon: The logic of sensation*, Smith, D. (trans.), Continuum, UK, 1989, pp.42-43
[45] May J. and Thrift N. (eds), *Timespace: geographies of temporality*, Routledge, New York, 2001, p. 30
[46] Winkler, J., *Space, Sound and Time, 1990 – 2003,* Basel, 2004
[47] Mroczkowski, S. *Paul Klee [temps du peintre]*, L'Harmattan, Paris, 2002, p.80
[48] Deleuze, G., *Différence et Repetition,* Paris, PUF, 1969, pp.32-3

fact, it is this tension between difference and repetition that is identified as the generator of rhythm, and thus movement, whether in art, philosophy or nature.

Philosopher and urbanist Henri Lefebvre was to introduce rhythm as a means to understanding the urban environment, and claimed that '*everywhere where there is interaction between a place, a time and an expenditure of energy, there is rhythm'.* [49] Using this definition in connection with the concept of repetition and difference, we arrive at the definition of an urban rhythm as the approximate repetitions of the interaction of time, place and energy.

1.2 Rhythms of (Everyday) Life

So what sorts of rhythms can we observe in life? According to our identified characteristics of rhythm, we can observe rhythms manifested in various forms in life: geophysical, biological, technological, social or cultural in nature. Most evident are the great cyclical rhythms of nature - climatic, geological and geomorphological - from the cycles of the moon and the sun, to the tides of the ocean. Less noticeable are those of flora and fauna, energies and even objects, which seem *'only slow in relation to our time, to our body, the measure of rhythms'*.[50] As recognised by Lefebvre, there is *'nothing inert in the world'*. [51] Two types of rhythms can thus be recognised - cyclical (such as those of day and night), or linear (such are those of our movement). Linear rhythms can exist within cyclical rhythms, which results what is termed a '*nested'* rhythm. Life can thus be seen as a complex polyrhythmia, consisting of a multitude of rhythms of different scales. According to Clark, *'Rhythm, it seems, marks all manifestation of life'*[52]*.*

The types of rhythms which can be observed are dependent on the time period which interests us, whether daily, weekly, annual or seasonal frequency. Over the period of a day, we can observe the rhythm of our everyday lives. As observed by Felski, '*Everyday life is above all a temporal term. As such it conveys the fact of repetition; it refers not to the singular or unique but to that which happens "day after day".'*[53] Well-known to many of us, everyday life consists of a routine of activities – including those of home, work, school, and leisure – and our transitions between them. The repeated actions of people, their activity patterns and mobility, and their interactions with each other, can be seen to produce '*regular paths and points of spatial and temporal intersection'*[54]. These repeated activity patterns are described by urban geographer Anne Buttimer as the *'orchestration of various time-space rhythms'*[55]. Thus by analyzing our everyday rhythms, we can begin to better understand the role of their organizing structures. As will be seen in the following section, on a collective basis, this rhythmic organism is the urban structure of the city.

[49] Lefebvre, H. *Rhythmanalysis: Space, Time and Everyday Life*, Continuum, London, 2004, p.15
[50] Lefebvre, 2004, p.17 in Edensor, 2010, p.7
[51] Ibid.
[52] Eric Clark, 'Rent Rhythm in the Flamenco of Urban Change', in Mels, T., *Reanimating Places Places - A Geography of Rhythms (Re-materialising cultural geography*), Ashgate, UK, 2004
[53] Felski, R., **'**The invention of everyday life**'**, New Formations 39, 2000, p.18
[54] Edensor, T., *Geographies of Rhythm: Nature, Place, Mobilities and Bodies*, London, Ashgate, 2010, p.8
[55] Buttimer, A. 'Exploring the dynamics of lifeworld'. *Annals of the Association of American Geographers*, 1976, 66 (2), p.289

1.3 Rhythms of the City

Rhythm has always marked the lives of people but as recognised by Lefebvre, these rhythmic characteristics really *'only became visible as urbanisation allowed the observation of uniform and repetitive aspects of social existence'*.[56] The processes of urbanisation have in turn influenced the nature of our everyday rhythms. Sometimes the urban infrastructure and their respective schedules work to support our rhythmic needs, and sometimes we suffer from their spatial and temporal limitations. Urban living has often been described as a *'rhythmic composition'*[57], and in addition to the rhythms of the natural environment previously described, the following main groups of urban rhythms can be observed: those of people; their bodies; and their mobility. [58] Each of these rhythms will be described below.

Rhythms of people

Described as the *'routine, daily flows of people through space and place'*[59]*,* these consist of the routine daily tasks of people as structured by their respective timetables. Commuters, shoppers, students, tourists all have their specific schedules, in contrast to the less-ordered rhythms of the unemployed and homeless. These rhythms are subject to the natural rhythms of day and night and the seasons, as well as the man-made rhythms of public transport schedules, opening hours, and lighting times.

Rhythms of bodies

Internal bodily rhythms include our breathing, pulses and blood circulation. The embodiment of rhythms is recognized as central to our understanding and measurement of environmental rhythms.[60] At the same time as we can compare and contrast our internal rhythms with external rhythms, we can also regulate them through repetitive training – what Lefebvre called 'dressage'. The meeting of one rhythm with another is also known as 'entrainment'. The 'absorption' of external rhythms into the body through repetition and practice allows its adoption as 'second nature', such as when learning a new dance. The corporeal sensing of rhythms is vital to our subjective and cultural experience of place.[61]

The rhythms of mobility

Our rhythms of mobility include those of our transportation, whether the collective transport networks of train, tram and bus, the more independent rhythms of the car and bike, or the most corporeal rhythm of walking. Regulation of these traffic flows is implemented in the form of traffic lights, speed limits, road layout and driving conventions. These rhythms are characterised by their tempo, pace and regularity, and determined by the mode and style of travel. Rhythms of mobility can act to inform sense of place in several

[56] Felski, 2000, p.16
[57] Crang, 2001, p.191
[58] Edensor, 2010, p.4
[59] Ibid.
[60] According to Lefebvre, in Edensor, 2010, p.5
[61] Edensor, 2010, p.5

ways: by the dynamic effect they give a place as they flow through it; by becoming a 'mobile place' in themselves; and then by producing a mobile sense of the being travelled through.[62]

Thus our urban lives can be seen as the interaction of our bodily rhythms, whether internal or external, with our surrounding urban environments. As identified by Crang, *'the urban place or site is composed and characterised through patterns of these multiple beats.'*[63] Place itself can be seen as the dynamic intersection of time and space - the interaction of urban flows and urban form. Once realising that *'Instead of being a solid thing, the city is a becoming, through circulation, combination and recombination of people and things.'*[64], we can begin to understand the implications of static urban design on the overall urban dynamic.

1.4 Implications for Urban Design

As the spatial structure within which we live out our everyday activities, the physical design of our cities plays an inevitable role in determining our everyday rhythms. As noted by Relph, *'the manifestations of time in activities, objects, and buildings contribute to an overall temporal pattern.* [65] The spatial composition of buildings and infrastructure cannot help but influence the temporal flows of people and their relative activities. As such, each city can be observed to have its own rhythmic characteristics due to its spatial urban design. Thus, to a degree, we can 'design' our urban rhythms.

Urban design rhythms include the morphology of the form itself (also known as the urban fabric), the urban activities it houses, and the street networks and infrastructure systems which connect them. These rhythms have an inevitable effect on issues of accessibility and connectivity, and the resulting urban activity (or lack there of). The form of our cities should ideally support both the rhythms of our everyday lives and those of our natural environment in a sustainable way. However technological developments – from the car, high-speed infrastructure, to the virtuality of the internet – have changed the relationships between space and time, and in turn our spatial rhythmic needs. The spatial design of our cities is often slower to adapt, and urban problems such as traffic congestion and urban sprawl result. This calls for new approaches to urban design in order to cater for these changing rhythms.

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[62] Ibid., p.6
[63] Crang, 2001
[64] Crang, *Rhythms of the City* : Temporalised space and motion', 2001. In J. May and N. Thrift (eds), *Time/Space: Geographies of Temporality,* 2001, p.190
[65] Relph, 'Temporality and the Rhythms of Sustainable Landscapes', 2004, p.113, in Mels, *Reanimating Places - A Geography of Rhythms (Re-materialising cultural geography*), Ashgate, UK, 2004

1.5 Significance for Sustainability

In recent years, urban geographers have brought attention to the importance of rhythm in addressing our current sustainability crisis: Anne Buttimer, in her 2001 book *Sustainable Landscapes and Lifeways*, recognizes that *'issues of sustainable development… inevitably involve nature and its multiple rhythmicities'*[66]; Tim Edensor in his recent book *Geographies of Rhythm* (2010) recognizes that *'the rapid acceleration of climate change may require a shift in thinking rhythmically'*; and James Evans highlights the *'urgent imperative to develop new economic and social rhythms which are better attuned to the quickly mutating ecological rhythms that signal impending catastrophe.'*[67] Problems of urban sustainability are being increasingly viewed in terms of the relationship between our various social, economic and environmental rhythms. As observed by Relph, *'… sustainability is above all a concept about time.'*[68]

One main criticism of the rhythms of contemporary life is the imbalance of the linear over the cyclical – *'That these (social) rhythms have become more complicated than natural rhythms is highly probable. A powerful unsettling factor in this regard is the practico-social dominance of linear over cyclical repetition – that is to say, the dominance of one aspect of rhythms over another.'*[69]

An example is the over-riding linearity of the desire for economic growth (e.g. the stock exchange) which has resulted in the 24-hour working city without respecting the cycles of nature, including those of the human body. Financial centres such as New York and Tokyo are known for their night-time conveniences, yet little thought is given to those who must work to provide it.

Another rhythmic disruption is the increasing 'polychronicity' of the city, criticised for its '*shattered and fragmented times where we see less rhythms than disjointed tempos'.* For example, the endless juggling of work with household rhythms, or the loss of communal meal-times and thus family time. Not least is the effect of telecommunications technologies, such as the internet or mobile phones. Through such digital connection of different locations in real-time, we are able to perform tasks in multiple places as well as travel time zones. These spatio-temporal changes in our lives can be seen as responsible for the restructuring of wider social patterns. Thus it will become increasingly important to address urban rhythms in the future.

[66] Buttimer, 2001, p.7
[67] Edensor, 2010, p.7
[68] Relph, 2004, p.111
[69] Lefebvre, 2004

Conclusions: The need for more rhythmical cities

As discussed above, many urban problems can be viewed rhythmically. Conflicting rhythms can indicate infrastructure problems of congestion, connectivity or accessibility. The recognition of such moments of rhythmic crises, or what Lefebvre was to term *'arrhythmia'*, is the first step to resolving them. For example, an absence of rhythms may indicate 'dead' zones in the city in need of revitalization. Thus rhythm can be used as an approach towards urban regeneration and the reanimation of social space and place, [70] as is proposed by Mels in his book *Reanimating Places:* [71]

'*To reanimate places is to register the close harmony, dissonances, and transpositions in the polyphony of places and tempos beyond reified existence. It reminds us how social rhythms are in fact lived and cannot be separated from the complex everyday experience of human beings in their diverse social and material environments.'* [72]

With many of our social, cultural and environmental problems being identifiable in terms of rhythm, a rhythmical approach to resolving them can be seen as a useful, if not necessary, approach to addressing our current urban sustainability crisis. In the next section, we will explore how urban rhythms have so far been analysed in urbanism and other related fields including philosophy, Time Geography and Soundscape Studies.

[70] Mels, 2004, p.24
[71] Ibid., p.26
[72] Ibid.

2 Analysis of Urban Rhythms

As we have seen, cities are constituted of a variety of urban flows, whether physical, social or environmental. These flows have rhythmic effects on urban experience and sustainability, and it is not enough to consider the design of a city as a static object. A more dynamic approach to urban design is called for, which deals with the flows it composes and the rhythms they produced.

In order to develop a rhythmic approach to urban design, we explore related fields in which urban rhythm has been previously addressed. In addition to urban design, these include: Philosophy, and the Rhythmanalysis theory developed by Bachelard in the 1930's and later by Lefebvre; Time Geography, and the call for temporality in geographic mapping in the 1970's; and Soundscape Studies, concerned with the acoustic quality of the urban environment.

2.1 A Philosophy of Rhythmanalysis

A concern with the rhythmic nature of urban life attracted much interest in the field of philosophy during the 1930's. The term 'Rhythmanalysis' is first attributed to Brazilian philosopher Lucio Alberto Pinheiro dos Santos, in his work *La Rhythmanalyse* of 1931. It inspired philosopher Gaston Bachelard to develop his own rhythmic theory in the 1930's:

'I once said that by examining the rhythms of life in detail, by descending from the great rhythms forced upon us by the universe to the finer rhythms that play upon man's most exquisite sensibilities, it would be possible to work out a rhythmanalysis…' [73]

French philosopher Henri Lefebvre was to develop Bachelard's rhythmanalysis to our everyday urban lives. A Marxist concerned with our 'rights to the city', Lefebvre used the notion of rhythm in his analysis of social practices and their relationship to those of nature.[74] The Rhythmanalysis of Lefebvre was intended as a *'theory, practice and mode of analysis for the understanding of one's environment through the experience of its rhythms'*[75]. The proposed 'practice' of such a *Rhythmanalyst* was through the act of 'listening' to the relationship between different rhythms:

'He listens – and first to his body; he learns rhythms from it, in order consequently to appreciate external rhythms. His body serves him as a metronome.' [76]

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[73] Bachelard, *The Poetics of Space*, Beacon Press Books, USA, 1994, p.65
[74] Lefebvre, *A Critique of Everyday Life*, London, 1991, p.117
[75] Elden (ed.), 2004, xiii
[76] Lefebvre, 2004, p. 19

Thus Lefebvre was concerned with the *'phenomenological description of the relationship between the body, its rhythms and surrounding space*'.[77] To Lefebvre, central to an understanding of rhythm was its bodily experience. The body remains the first point of analysis and acts as a 'measure' of the surrounding environmental rhythms[78]. However, being instantaneous in nature, a rhythm must be simultaneously 'caught' and perceived. Thus a Rhythmanalyst must become both participant and observer, viewing a rhythm from the point of view of oneself, as well as being the observer of many.

2.2 Time Geography

Rhythm has become an increasingly important part of the field of geography due to the changing fluxes of the modern city. A growing interest in the temporal nature of place and space led to the birth of the field of Time Geography in the 1970's. Swedish geographer Torsten Hägerstand, and his colleagues at the Institute of Geography, University of Lund, called for a more dynamic approach to a traditionally spatial discipline. The study of place became just as much about time as about space. Central to the discipline is the concept of an integrated *'Time-Space'*, with the realization that we are continually moving in time *'even when we remain completely motionless in space'*.[79] The term has come to refer to the *'analysis of human activity patterns and movements in space-time'*.[80] However, approaches remain preoccupied with quantitative analysis – the measurable and mappable.[81] This led Hägerstrand to call for a more temporal approach to geography:

'We need to rise up from the flat map with its static patterns and think in terms of a world on the move, a world of incessant permutations'.[82]

Human activities were proposed as *'space-time trajectories of matter'*[83] and Hägerstrand attempted to map the temporal dimensions of these trajectories. With time on the vertical axis, the trajectories of people were overlaid horizontally onto 2D space. The various institutions - from the workplace, school, shops, and house - formed time-space anchors, and the opening hours of their activities formed 'envelopes of space-time' that constrain and thus synchronize behavioural patterns.[84] These 'prisms of time-space opportunity' also show what is possible given the limits of time and mobility. Depending on the time period, daily, weekly or seasonal patterns of repetition and routine could be mapped, observable from afar as *'a ballet of lines of motion.'*[85].

[77] Lefebvre, 1996, p.30 Trans. Kofman, *Writings on Cities*, Blackwell Publishers, UK
[78] as proposed by Klee and Deleuze
[79] Hägerstrand, 1991, p.141
[80] Kwan, M.P., Lee, L., 'Geovisualization of Human Activity Patterns Using 3D GIS. A time-Geographic Approach'. in Goodchild, M.F., Janelle D.G., *Spatially integrated social science*, Oxford University Press, 2004, p.48-66
[81] Crang, 2001, p.192
[82] Ibid.
[83] Hägerstrand, 1989, in Gren, 2001, p.217
[84] Crang, 2001, p.192
[85] Ibid., p.193

2.2.1 Time Use Research

The study of how we use our time has become of increasing concern to sociologists, particularly due to the changing rhythm of our contemporary lives. It has been observed that we now work longer hours, including the weekends, travel more for leisure, and have 2.5 – 3 hours of free time. This has led to the establishment of the *International Association of Time Use Research (IATUR)*, aimed at understanding our social human movements in both space and time. With many European countries already having their own system of analysis, a *'Harmonized European Time Use Survey' (HETUS)* was established in the late 1990's for comparative reasons.[86] This provided a common structure for data collection of the use of time, including a comprehensive *Activity Coding List (ACL)*, whose main activity categories can be seen in Table 2.1. At the same time, it allows for the specific cultural practices of the individual countries, currently encompassing 15 European countries.

Table 2.1: Main categories of the HETUS Activity Coding List (ACL)[87]

CODE	ACTIVITY
0	PERSONAL CARE
1	EMPLOYMENT
2	STUDY
3	HOUSEHOLD AND FAMILY CARE
4	VOLUNTARY WORK AND MEETINGS
5	SOCIAL LIFE AND ENTERTAINMENT
6	SPORTS AND OUTDOOR ACTIVITIES
7	HOBBIES AND COMPUTING
8	MASS MEDIA
9	TRAVEL AND UNSPECIFIED TIME USE

The main method of data collection is through the *Time Use Survey (TUS)*, as seen in Figure 2.1 below. Participants of a region are asked to keep a diary of their activities on a given day, according to the Activity Coding List. The principal (and secondary) activities performed, the place or transport means, as well as other present acquaintances, are recorded over a 24-hour period. The minimum time interval is ten minutes, thus providing quite a high level of detail.

The Time Use Survey can be seen as a highly subjective analytical technique, with each rhythm being the result of much personal reflection. However, the locations of these activities, and thus the spatio-temporal movements of the people, are undefined. Thus, while the question of '*What were you doing?*' is quite detailed in the specification of the urban activity carried out, the question of '*Where are you?*' asks for a descriptive response of 'at home, at friends' home, at school, at workplace, in restaurant, in shop', which infers again the activity rather than the geographical location itself. Similarly, the mode of transport asks for the vehicle type rather than the actual line taken. Collectively, this data can indicate 'how' a population generally spend their time in a city. However 'where' it is spent is unclear.

[86] Harmonised European Time Use Survey, https://www.h2.scb.se/tus/tus/ [Accessed November 2012]
[87] Ibid., p.110

Time	**What were you doing?** Record your main activity for each 10-minute period from 10.00 to 13.00! Only one main activity on each line! Distinguish between travel and the activity that is the reason for travelling.		**What else were you doing?** Record the most important parallel activity. Indicate if you used, in the main or parallel activity, a computer or internet. You do not need to record the use of a computer or internet during working time.		**Where were you?** Record the location or the mode of transport e.g. at home, at friends' home, at school, at workplace, in restaurant, in shop, by foot, on bicycle, in car, on motorbyke, on bus, …		**Were you alone or together with somebody you know?** Mark "yes" by crossing	With other household members				
							Alone	Partner	Parent	Household member up to 9 years	Other household member	Other persons that you know
10.00-10.10	Work	111	Coffee break*		Workplace	13	☐	☐	☐	☐	☐	☒
10.10-10.20							☒	☐	☐	☐	☐	☐
10.20-10.30							☒	☐	☐	☐	☐	☐
10.30-10.40							☒	☐	☐	☐	☐	☐
10.40-10.50							☒	☐	☐	☐	☐	☐
10.50-11.00							☒	☐	☐	☐	☐	☐
11.00-11.10							☒	☐	☐	☐	☐	☐
11.10-11.20							☒	☐	☐	☐	☐	☐
11.20-11.30							☒	☐	☐	☐	☐	☐
11.30-11.40	Lunch break: had lunch	021	Talked with colleagues	121	Canteen		☐	☐	☐	☐	☐	☒
11.40-11.50	--"--		--"--		--"--		☐	☐	☐	☐	☐	☒
11.50-12.00	--"--		--"--		--"--		☐	☐	☐	☐	☐	☒
12.00-12.10	Lunch break: went to the supermarket	936			On foot	21	☒	☐	☐	☐	☐	☐
12.10-12.20	Lunch break: bought food	361			Supermarket	16	☒	☐	☐	☐	☐	☐
12.20-12.30	Lunch break: went back to work	936			On foot	21	☒	☐	☐	☐	☐	☐
12.30-12.40	Work	111			Workplace	13	☒	☐	☐	☐	☐	☐
12.40-12.50							☒	☐	☐	☐	☐	☐
12.50-13.00							☒	☐	☐	☐	☐	☐

Figure 2.1: Harmonized European Time Use Survey (HETUS) - Coding diary example[88]

Geolocalised Tracking

A more detailed study of travel data can now be performed with Global Spatial Positioning (GSP) technology. This allows the precise tracking of our urban movements, showing the details of a trajectory between an origin and destination. It also allows the automatic collection of such space-time data and its analysis on an even wider scale. A landmark project is the *STAR Space Time Activity Research*[89] project in Halifax, Canada, which involved the tracking of more than 2,000 households across the Halifax Regional Municipality. Information concerning the nature, timing and location of residents in different neighbourhoods were collected via GSP tracking.[90] Contrary to the subjective reflection required by the Time Use Survey, this approach can be seen to objectify the rhythms of our everyday urban movements.

Real-time tracking

The geolocalisation of mobile networks is also allowing the tracking of the urban population in real-time. One of the first public attempts to do so is the *Real Time Rome* project *(2006)* by the MIT SENSEable City Lab, which used the geolocalised signals of mobile phones in

88 Eurostat, *Harmonised European time use surveys, 2008 guidelines*, European Commission, 2008, p.201

89 Harvey, A.S., *Halifax Regional Space-Time Activity Research (STAR) Project - A GPS-Assisted Household Time-Use Survey*, St. Mary's University, Halifax, Canada, 2009

90 http://www.acoa-apeca.gc.ca/eng/ImLookingFor/ProgramInformation/AtlanticInnovationFund/Pages/Springboard_SMU.aspx [Accessed September 2012]

order to '*reveal the rhythm of the city as it occurs, in real time*'[91] over one specific night in Rome. From the intensity of cellphone usage at different places over time, the movement of the urban population could be deduced. Figure 2.2, below, represents the cellphone activity as a mesh over the city, indicating 'where the people are'. This information can be used to determine crowd movement during special events, the location and concentration of tourists, and the popularity of urban landmarks or other places of interest.

Real-time tracking of urban rhythms over longer periods of time will allow urban planners to better accommodate for crowd flows and urban designers to better understand urban space usage. However, the release of private mobile data of course raises questions of privacy and will most probably ensure its future utilisation only on an anonymous, collective basis.

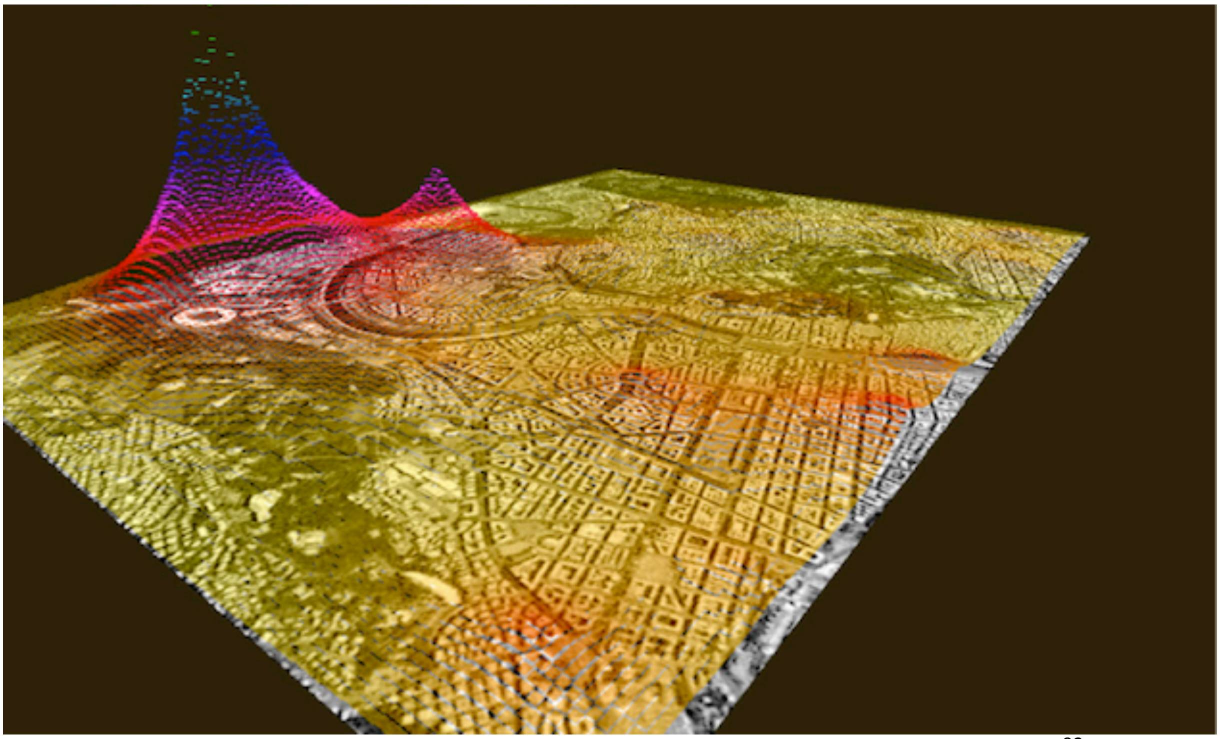

Figure 2.2: Cellphone activity during a Madonna concert in Rome, 2006 [92]

2.3 Urban Dynamics

In addition to population flows, other urban flows of interest include those of our transportation and natural environment and the relationships between them. These rhythms are afterall interrelated and together determine the resulting urban dynamic. In the example above, crowd tracking in combination with the geolocalisation of public transport and vehicular traffic was able to show the density of pedestrian population in relation to public transport services. In the following sections we will discuss in further detail the analysis of transportation and environmental rhythms.

[91] Ibid.
[92] http://senseable.mit.edu/wikicity/rome/images/RealTimeRome-MadonnaConcert.jpg [Accessed Sept.2012]

2.3.1 Transport flows

Technological advances in wireless mobile communication and sensing devices has also advanced the analysis of other urban flows contributing to the urban dynamic. One important rhythm that must be constantly reviewed is that of public transportation usage. With the growing urban population, as well as aging infrastructure, rising fuel costs, and environmental needs, this is of increasing concern to transport authorities.

Many city transport authorities are thus now recording the number of people using their services. With the increasing use of electronic public transport passes, and knowledge of the start and end destination of their journeys and the time taken, this information is becoming increasingly easy to record. Transport for London, for example, regularly updates network performance every four weeks, based on Oyster card electronic ticketing records.[93] This allows the analysis of the rhythm of London bus and tube usage over different days of the week, based taken over one week, and a better understanding of *'how, why and where we travel in London'.*[94] In Paris, the *L'observatoire des déplacements* conducts surveys and field observations to establish a synthesis of statistical data on trips to Paris in partnership with its various public transport authorities to determine the main indicators of travel modes in Paris each year.[95]

As a result of such studies, city transport authorities are better able to accommodate for the infrastructure demands of its citizens, improving travel time, accessibility, efficiency and dependability, as well as support a more sustainable relationship with the environment.

2.3.2 Environmental flows

Environmental data sensing is becoming increasingly common in urban analysis through the use of GSM mobile phone technology and various sensors. La Montre verte / City pulse[96] is a Paris-based initiative which uses environmental sensors and community participation for environmental monitoring. It consists of a 'Green watch' armed with a GPS chip, CO2 sensor and noise sensor as a measuring device for atmospheric pollution and noise. The geolocalised information is then visualized on an online platform as shown in Figure 2.3.

Sensors can also be attached to vehicles in order to collect environmental urban data, such as temperature, relative humidity and pollution levels, along transport routes. One initiative implemented in Copenhagen by the MIT Senseable City Lab was to integrate these sensors in city bikes.[97] Such crowd-sourced environmental data, linked with geolocalised transportation, is helping to increase our knowledge of how transportation and environmental flows may be connected.

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[93] http://www.tfl.gov.uk/corporate/modesoftransport/londonunderground/1592.aspx [Accessed Sept.2012]
[94] http://gisagents.blogspot.fr/2012/08/traffic-movement-in-london-from-travel.html [Accessed Sept. 2012]
[95] http://www.paris.fr/pratique/deplacements-voirie/dossier/bilan-des-deplacements-a-paris/rub_7096_dossier_103374_port_16333 [Accessed Sept 2013]
[96] http://www.fing.org/?La-Montre-verte-City-pulse-Green&lang=en [Accessed May 2013]
[97] http://senseable.mit.edu/copenhagenwheel/index.html [Accessed September 2012]

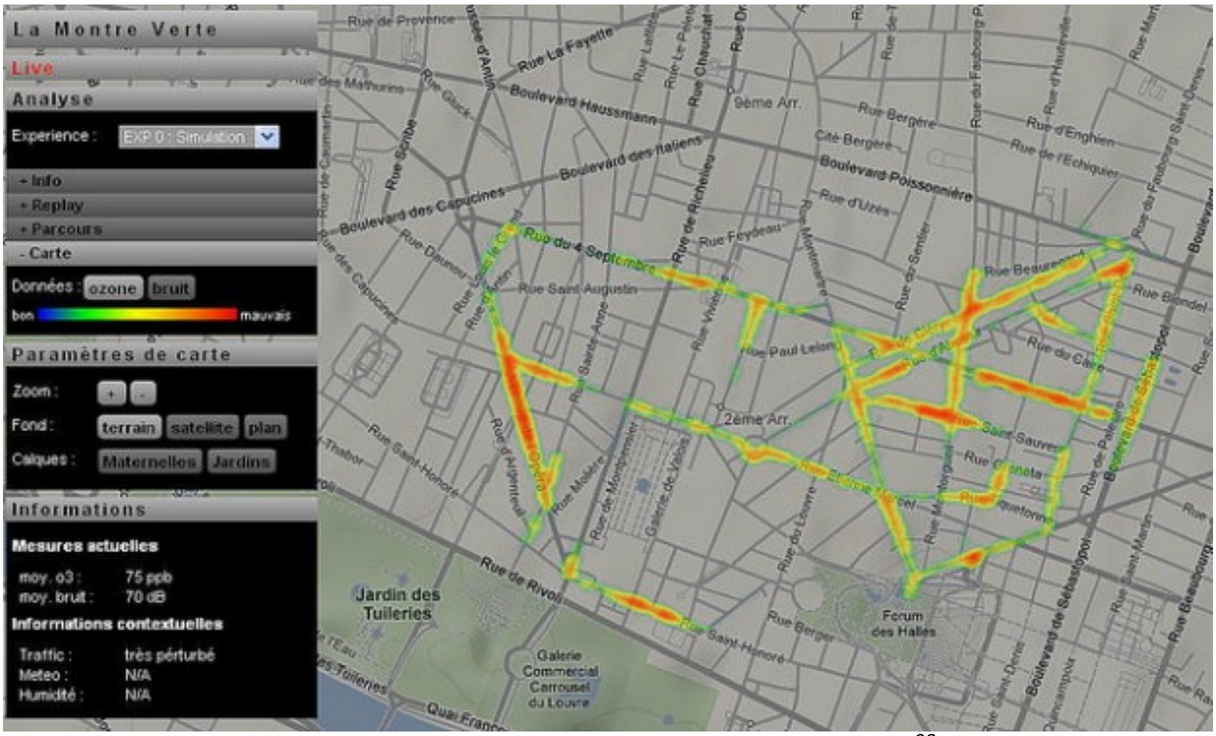

Figure 2.3: Le Montre Verte – City Pulse Interface[98]

On a global scale, Eye on earth is a 'public information network' for collaborative environmental measurement and observation. It is the result of a public-private partnership between the European Environment Agency (EEA), Esri and Microsoft, which has allowed public accessibility to measured environmental data.[99] Environmental data is collected from official sources before being visualised in interactive maps for public observation and commentary on local environmental quality. This platform thus allows both quantitative and qualitative assessment of environmental flows towards their participatory improvement. WaterWatch represents official water quality data while AirWatch represents near real-time data on three air pollutants.

NoiseWatch records noise levels and consists of official noise data or 'near real-time' noise measurements, as well as crowd-sourced noise data received via a mobile application. It also allows users to share their observations on the acoustic quality of their local environments, as shown in the Figure 2.4 below. [100]

[98] http://www.lemonde-des-plantes.com/montre-verte/ [Accessed May 2013]
[99] http://www.eyeonearth.org/ [Accessed May 2013]
[100] http://www.eyeonearth.org/en-us/Pages/Learn-More.aspx [Accessed May 2013]

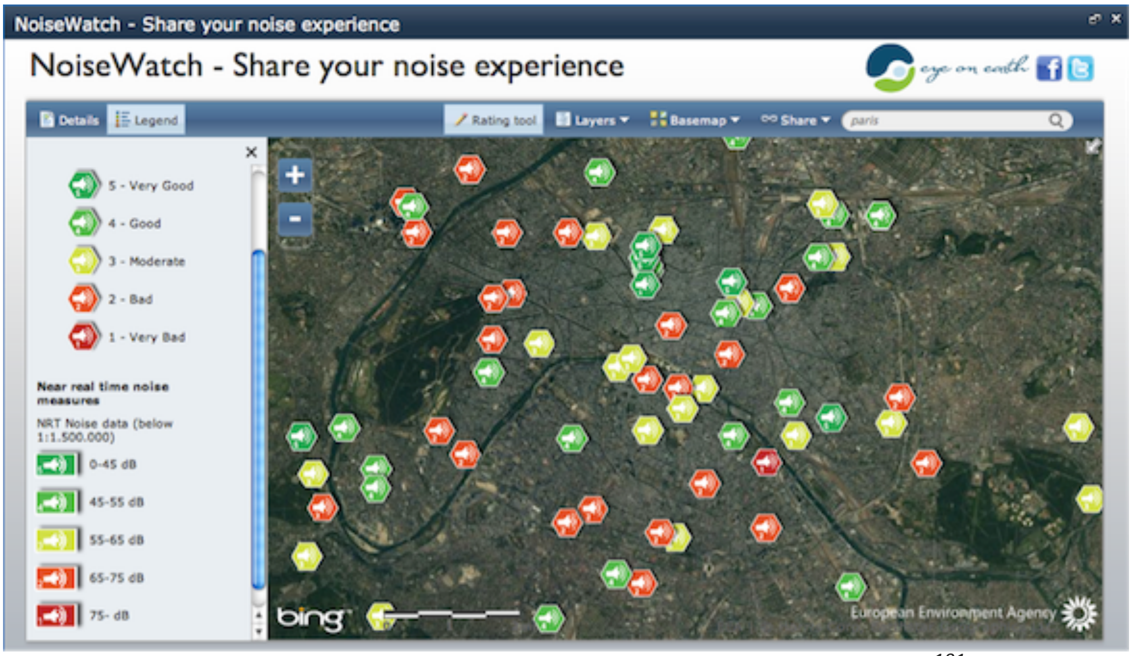

Figure 2.4: NoiseWatch – Interface for Noise contour maps [101]

NoiseTube[102] is a similar project based in Paris and Brussels promoting a participative approach to monitoring noise pollution. It is an example of how collaborative databases of shared user contributions (for example, through online social networking) is encouraging citizens to play an active part in monitoring the urban dynamic of their cities and understanding their role in it. Through a mobile phone app converting it into a geo-localised noise sensor. Citizens can measure their surrounding noise levels in dB(A), contributing to a collaborative map of noise pollution as shown in Figure 2.5, as well as allowing them to express their annoyance levels. Thus it allows community discussion on noise pollution, as well as contributing to the study of soundscapes, as will be explored in the following section.

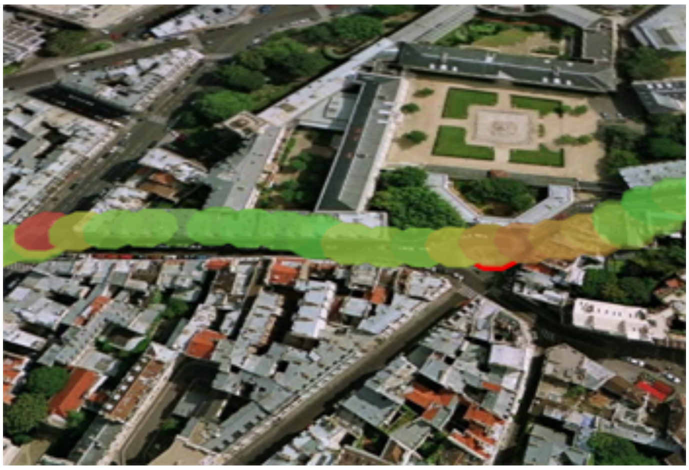

Figure 2.5: NoiseTube sound levels in dB(A) shown as colour-coded circles along a path.[103]

[101] http://eyeonearth.org/map/NoiseWatch/ [Accessed May 2013]
[102] http://www.noisetube.net/#&panel1-3
[103] http://noisetube.net/#&panel1-1 [Accessed May 2013], Sony Computer Science Laboratory Paris & VUB BrusSense group, 2008-2013

2.4 Soundscape Studies

Initiated by R. M. Schafer and his team at Simon Fraser University in the late 1960's, Soundscape Studies originated from a concern for the increasing effects of 'noise pollution' due to urbanisation. This concern was manifested most famously in the *'World Soundscape Project'*, which proposed *'the world soundscape as a macrocosmic musical composition'.*[104] Highlighting its musical qualities, it also brought attention to our responsibility, as composers and performers, for its aesthetic design, thus giving birth to the concept of 'soundscape design'. According to Murray Schafer[105] the soundscape is not an 'accidental by-product' of a society, but a 'conscious construction' of the acoustic environment we live in. [106]

The Soundscape is defined as the interpretation of the existing acoustic quality of a given environment: *'how the individual and society as a whole understand the acoustic environment through listening.'* [107] Therefore, as defined by fellow WSP member Barry Truax, it is a form of *'acoustic communication'*, rather than the *'acoustic environment'* itself. Schafer proposed the process of *"ear cleaning"* as an analytical way of listening in order to evaluate the quality of the soundscape and interact with it. [108] Hildergard Westerkamp proposed the *Soundwalk* in which we walk through our environment with the sole objective to listen to it. These analytical listening techniques can both be seen as developments of Lefebvre's Rhythmanalysis technique, where he also proposed 'listening' as a way of learning more about one's external environment.

The different aspects of the soundscape identified by Schafer and his colleagues were categorised as follows [109] and are still being used today in defining soundscapes:

- Keynote sounds

Background sounds, which over time contribute to the overall tonality of a place, including sounds of nature, such as the climate or wildlife, or more urban sounds such as traffic noise.

- Sound signals

Foreground sounds, which are consciously listened to, such as horns and sirens.

- Soundmark

A sound unique to an area (much like a 'landmark') which characterizes a community, such as a church bell.

After studying *The Vancouver Soundscape,* Schafer and his WSP team studied a number of soundscapes in Canada before touring Europe in 1975. The resulting *Five Village*

[104] World Soundscape Project. *The Music of the Environment Series*, R. M. Schafer (ed.), A.R.C. Publications, Vancouver, British Columbia, 1973-78, p.3

[105] R. M. Shafer, *Soundscape*, 1994

[106] de Gotzen, A., Polotti, P., Rocchesso, D., 'Sound Design and Auditory Displays', in Polotti, P., Rocchesso, D., (Eds.), *Sound To Sense, Sense To Sound - A State Of The Art in Sound and Music Computing,* Logos Verlag, Berlin, Germany, 2008, p.430

[107] Truax, Barry, *Acoustic Communication*, Ablex Publishing, USA, 2001, p.xviii

[108] de Gotzen, A., et.al., 2008, p.430

[109] R.M. Schafer, The Tuning of the World, 1977

Soundscapes project was the first comparative analysis of the soundscapes of five rural villages in Sweden, Germany, Italy, France and Scotland. A repeated study has more recently been made entitled *Acoustic Environments in Change (AEC)*[110], which has enabled comparative analysis of the change in the soundscape of the same cities over time.

The Soundscape Studies movement initiated by the WSP have inspired similar studies concerning acoustic environments, such as those of the Swiss countryside led by geographer Justin Winkler, which has contributed to the growth of the field of Acoustic Ecology.

2.4.1 The Time Geography of Soundscapes

While Soundscape Studies is primarily occupied with the nature of the sounds themselves, the organization of these sounds in time is just as important. As the product of an expenditure of energy, they are also a rich source of information of events happening in a place over time. Time-Geography thus has much to benefit from the soundscape as a source of analysis, as recognized by time geographers such as Albert Mayr and Justin Winkler:

> *'Time and space are essential dimensions in the sonic world. Oscillations of any scale are determined by a time-space ratio, by two quantities that condition each other mutually. Soundscapes are thus essentially manifestations of rhythmic systems, both in the sonic and subsonic realm, in their objective constitution and subjective evaluation.'*[111]

In fact, the objective of the Acoustic Environments in Change project was to answer the following geographical questions through the analysis of each city's soundscape:

i. What can the sounds of everyday life tell us about the social, economic, cultural and other aspects of a community?

and

ii. What social, economic, cultural and other phenomena do reflect themselves in the sonic environments of a community? … Which changes in particular do affect the sounds? [112]

The objective was to use the soundscape as an indicator of geographical changes, as well as to understand which changes influence the soundscape. In order to answer these questions, various methods have been used, both qualitative and quantitative. Schafer's study involved a range of field work activities including: sound preference questionnaires; vehicle counts; sound level measurements; 'sonic history' reconstruction; periodic recordings; sound walks; and the mapping of 'daily sound schedules and yearly sound calendars'.[113]

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[110] Jarviluoma H. et al. (eds.), *Acoustic Environments in Change & Five Village Soundscapes,* Tampereen ammattikorkeakoulu, Tampere, 2009

[111] Winkler, J., *Rhythmicity*, 2002, p.3, in Winkler, J., *Space, Sound and Time - A choice of articles in Soundscape Studies and Aesthetics of Environment 1990 – 2003,* Basel, 2004

[112] Mayr, A., *Soundscapes in Cembra 1975-2000*, Estratto da: SM Annali di San Michele – n.15/2002, Museo degli Usi e Costumi della Gente Trentina, 2002, p.145

[113] Ibid., p.146

The methods employed by the Swiss group of geographers in their analysis of 6 places in Switzerland also involved on-site observers, audio recordings and the measurement of sound pressure levels (SPL).[114] The mapping of sound pressure levels over a 24-hour cycle was used to create a 'time profile' of each particular place. The audio samples of a 'sonic day' allow the qualitative experience of the keynote sounds, including signal sounds and soundmarks. Plotting this day-long cycle of observations represented the overall 'tonality' of a place and the fluctuations which constitute it. The outcome, as seen in Figure 2.6 below, indicates the presence of two general rhythmic patterns: one which is relatively constant; and the other which drops during the night and rises during the day, in line with the rhythm of the sun.

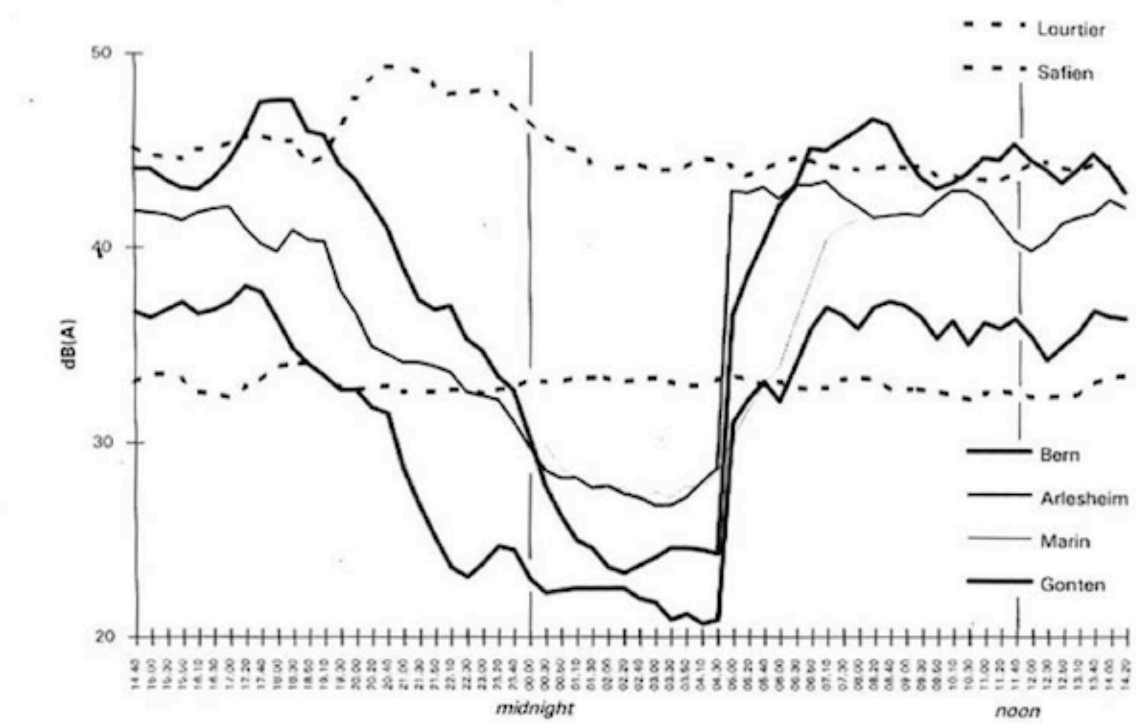

Figure 2.6: 24-hour-cycles of sound pressure levels in six cities in Switzerland (taken from 14.40h in the afternoon to 14.20h in the morning)[115]

2.4.2 Soundscape as an indicator of rhythm

'Nothing is more revealing to the soundscape analyst than to monitor the changes in an acoustically rich environment over some lengthy period of time.'[116]

As noted by Mayr, the use of the aural sense as an indicator of the environment has been *'rarely asked in the social science or human geography'*. One reason is that sound, 'due to its volatile nature, is regarded as an unreliable source of information in academia

[114] Winkler, 2002, p.3
[115] Winkler, 2002, p.4
[116] Truax, 2002, p.73

undertakings.'[117] However, its potential as a way to understanding a place is becoming recognized over recent years, particularly due to the ACE study, which showed that *'There appears to be a strong, but yet to be explored, link between sound and the sense of place.'*[118]

This link between sound and place is embodied in the presence of rhythms. Rhythm, as we have seen, expresses itself in both sound and the connection of time and space. As noted by Truax, *'sounds exist in time, and to a large extent, they create and influence our sense of time. There it is not surprising that our sense of the character or coherence of an environment is closely tied to the temporal relationships exhibited by sound'.*[119] This ranges from the sound's internal behaviour over time, to rhythmic patterns at various scales, up to whole cycles seen at larger time scales. This can be seen in sound level graphs of recordings taken at both daily and yearly time scales.

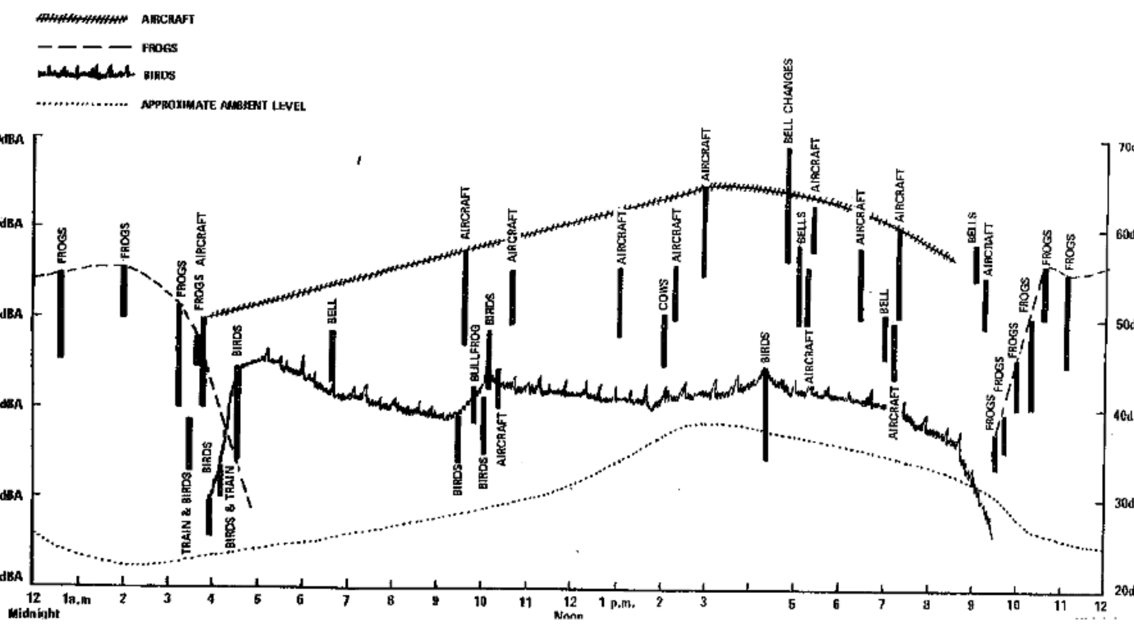

Figure 2.7: Daily pattern of sound levels, with sound sources, revealed by 24-hour recordings of the Summer Soltice of 1974, British Columbia[120]

In Figure 2.7, the different types of rhythms are discernable: the loudest and most consistent curve being aircraft, followed by the fluctuating curves of birds and intermittent appearances of frogs throughout the day. The approximate ambient sound level also shows a peak during the afternoon and a drop overnight. The soundscape can thus be seen as an indicator of the rhythms of a particular place.

[117] Mayr, 2002, p.145
[118] Ibid., p.147
[119] Truax, 2002, p.73
[120] Truax, Handbook for Acoustic Ecology, British Columbia, A.R.C. Publications, 1978

Conclusions: *Between Time Geography, Rhythmanalysis & Soundscape Studies*

'Where Lefebvre sought to change our understanding of the city by unpacking the phenomenology of the place as object, time-geography too often ended up dealing with the measurable and evident – indeed, the mappable.'[121]

Hägerstrand's 'constrained time-space interaction' and Lefebvre's 'time-soaked place' reveal a fundamental difference between the two analytical approaches.[122] The first is objective in its externalised point of view, while the second is subjective in its internalisation. Yet the city is neither a rhythmic machine, nor a theatre for corporeal experience.

While the objective mapping of spatio-temporal human movement in Time Geography is useful in better understanding human activity patterns in a particular place, this object method can be seen to ignore the experiential aspect of time-space.[123]

At the same time, Lefebvre's subjective Rhythmanalytical approach to understanding the shaping of human experience in everyday life, still requires much development to fulfil his proposal for an 'analytical science'. Lefebvre proposed listening to the city 'as an assemblage of different beats.'[124] If we were to take this listening literally, what rhythms would we hear?

The recordable soundscape shows great potential in the communication of some environmental rhythms. However, while it may act as an indicator of the audible rhythms in the environment, not all rhythms can be heard. Neither can we assume that the sonic relationship between the two is directly proportional to the relationship of interest. Furthermore, it is difficult to isolate the sounds of the rhythms we want from the rhythms we do not. These issues will be addressed in Part 2, and in our development of a technique for both the internal and external analysis of rhythm.

[121] Crang, 2001, p.192
[122] Ibid.
[123] Tim Edensor, 2010, p.2
[124] Crang, 2001, p.189

3 Organisation of urban rhythms

As varied as the types of urban rhythms identified, are the various attempts to organise them. In this chapter we first discuss their physical design in urban and transport planning; before exploring their control by political and cultural movements; and the regularizing role of social policies as implemented by Time Offices. Finally, we introduce the relatively recent field of soundscape design.

3.1 Urban design and Transport planning

Urban design has an inherent role in organising urban flows and generating urban rhythms. It physically structures our opportunities and constraints, telling us where we can go and how long it will take to get there, as well as our resulting rhythmic experience of this route. Unfortunately, the static nature of urban form itself has meant that its role in structuring temporal flows is often marginalised by a preoccupation with formal aspects. As called for by Batty and Cheshire: *'our focus should no longer be on location, but on interactions and connections, on networks and the concomitant processes that define flows between places and spaces'.*[125]

Batty and Cheshire describe a '*flow continuum',*[126] ranging from abstract activity changes, such as growth or decline, and changes in attributes, to physical, electronic, and social relationships based on material, digital, and personal flows. Similarly, they acknowledge that there is a continuum of infrastructure that houses them: from wireless media to fixed wires to physical containers, even to more abstract relationships that define social links.

In order to design for these urban flows, we must be able to focus on the temporal effects of the urban structure rather than simply its spatial design. Thus, a rhythmic approach to urban planning is called for and raises the question of how we can essentially 'design in time'.

Our transportation infrastructure has inevitability impacted greatly on the built design of our cities, with the urban fabric evolving according to our transportation modes. The mere speed of travel can be seen to change the spatio-temporal composition of the city and the meaning of space. Medieval cities for example were built to the scale of the pedestrian and relied on the need to walk. Faster train lines have also changed spatio-temporal relationships, with travel between cities making geography almost negligible. One example is the high-speed train connection between Paris and London, now only 2.5 hours away and allowing intercity commuting.

[125] Batty, M., Cheshire, J., Environment and Planning B: Planning and Design 2011, volume 38, p.195
[126] Batty, M., Cheshire, J., 2011

The invention of the automobile allowed us to build at a much larger scale and is largely blamed for our cities of sprawl. Urban planners have since been preoccupied with the mitigation of these traffic flows, oriented towards increasing efficiency and speed. This information is now available online in real-time to assist road users in avoiding traffic jams, as shown in Figure 3.1.

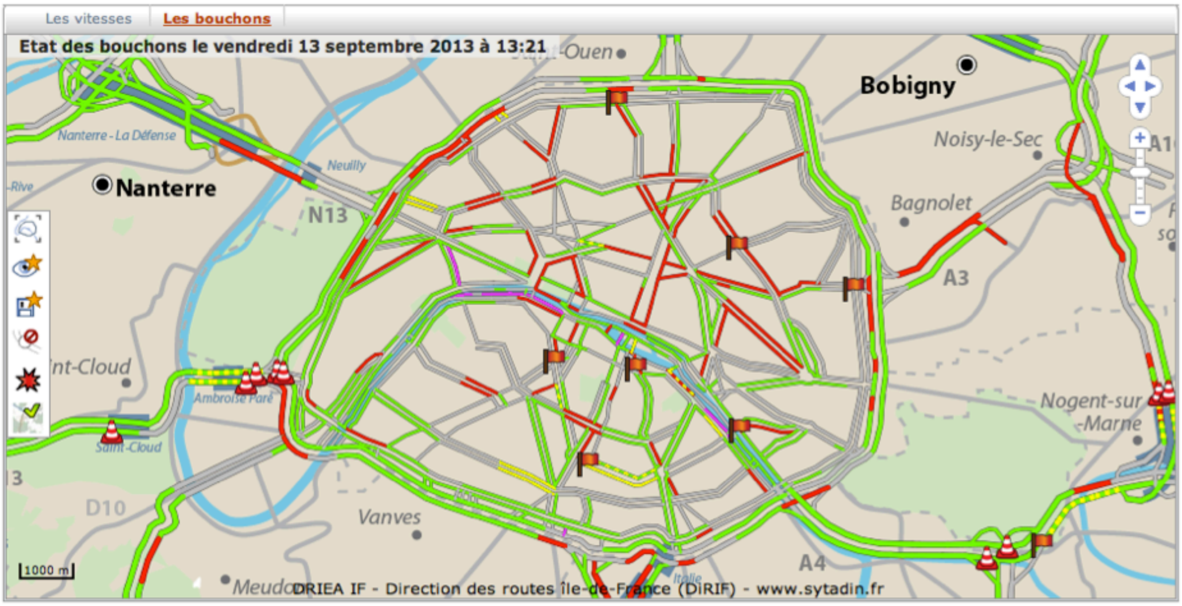

Figure 3.1: Real-time traffic map of Paris [127]

This has in turn greatly affected the experience of the pedestrian. Recent attempts to 'reclaim the city', as seen in the formation of a Slow Movement, has resulted in the creation of pedestrian zones and the reduction of traffic speeds in some cities. Such initiatives hopefully indicate greater respect for the rhythms of urban experience as well as those of the environment.

However, with the increasing carbon emissions and fuel shortages, a concern for sustainability is placing more emphasis on public transport systems. With the provision of public transport infrastructure unable to keep up with demand, transport authorities are trying to optimize existing resources. Using open data and crowdsourcing, French national railway company SNCF's Tranquilien mobile application [128] is able to forecast public transport flows. Through a colour-coded interface, passengers can make more informed decisions on where to find a seat, thus helping to streamline crowd flows on the transilien and regional train lines in the Paris region. Rather than using sensors, it relies on real-time passenger flow information fed from their smartphones. It also encourages user feedback concerning journey comfort, and encourages passengers to participate in their city's traffic management.

[127] http://www.sytadin.fr/ [Accessed Sept 2013]

[128] Trassard P., http://www.atelier.net/en/trends/articles/tranquilien-combines-open-data-and-crowdsourcing-streamline-public-transport-flows_422586, July 04, 2013

3.2 Time Politics

The relationship between rhythm and social power was first recognised by Lefebvre in his Rhythmanalysis of Mediterranean city-states including Athens, Roma, Venice and Marseilles, where he acknowledged that *'…diffuse forms of power often seek rhythmic conformity and spatio-temporal consistency through the maintenance of normative rules and conventions about when particular practices should take place at particular times…'*[129]. He noted that power *'knows how to utilize and manipulate time, dates, time-tables'*[130] recognizing that to control the time of a society is to regularize social behaviour. We must remain aware of the fact that the rhythm of a place is often under political control. Furthermore, rhythm has traditionally been a defining characteristic of a place and its culture. As recognized by Edensor, *'rhythmic rituals and habits…produce places, landscapes and nations as recognizable and shared entities'.*[131]

In recent years there has been an increasing trend towards the homogenization of these rhythms, which can be attributed to globalization. The *Slow Movement* is a time-based manifesto against the increasing tendency towards speed. Initiating in Italy from the now widely-spread Slow Food movement, created against the growing dominance of fast food, *'Città Slow'* applies a similar argument to urban living. The movement is against 'the fast-lane, homogenised world', valuing tradition and reclaiming time in the name of sustainability. With membership limited to cities with a population of less than 50,000 residents, the movement publicises that *'Slow cities have less traffic, less noise, fewer crowds.'*[132] In addition to the concern for transport flows, acoustic pollution and population density, other urban factors of concern include: environmental policy, infrastructure, quality of the urban fabric, encouragement of local produce and products, hospitality and community. The breadth of the Slow Movement indicates how large a part speed and rhythm governs our lifestyle and the social and environmental consequences attached.

3.3 Social Time Policies

Social life is regulated by the synchronization of everyday rhythms. From the organization of work and school hours, to the regulation of opening hours, and attempts to juggle night-life noise levels with residents sleeping patterns, municipalities are increasingly implementing social time policies – effectively telling us *'when to rest, work and play'.*[133] In fact, as recognized by Edensor, *'everyday synchronization, the simultaneous participation of millions of people in timetabled routines… is a fundamental principle of social organization'* [134]

The conception of metropolitan *Time Offices* can be seen as the ultimate attempt to synchronise a society, which implement projects and activities related to the organization of

[129] Edensor, 2010, p.11
[130] Lefebvre, 2004, p.68 in Edensor, 2010, p.11
[131] Edensor, 2010, p.10
[132] http://www.slowmovement.com/slow_cities.php [Accessed October 2010]
[133] Edensor, 2010, p.11
[134] Ibid., p.10

time in a city. A European network of Time Offices was recently established called the *'Network of European Cities of Time'*[135] and its' growing membership includes municipalities in Spain, Italy and France. In France, most local administrations have a Time Office *('Bureau de Temps')*.[136]

The Time Office of the City of Paris, publicised in the brochure of Figure 3.2, was established in 2002 in order to ensure that the organization of public services in Paris '*more accurately reflects the lifestyles of users and employees'*. The City of Paris acknowledged that working habits had changed dramatically over the past 10 years, with one third of Paris citizens required to work in evenings or weekends. Furthermore, journeys are no longer limited to travelling between home and work, with more than half made for leisure.

The Time Office attempts to better understand the way of life of citizens through public consultation, and identify the needs and constraints of users. Through dialogue between internal (council) and external partners (institutions, businesses, unions etc.), it attempts to reconcile the temporal needs of its citizens with the appropriate provision of public services, as well as attempting to maintain gender equality and avoid exclusion.

Thus the Time Office is addressing such lifestyle changes such as work, transport and leisure habits, claiming that the city '*is changing to reflect the way you live your life'*. However, it also claims to 'protect' its citizens from undesirable rhythms, such as the '*24-hour city'*.[137] Thus the contrary can in fact be seen – the city is changing to control the way we live our lives. Consciously or not, social values are being enforced through temporal organisation.

Figure 3.2: Brochure of the Time Office of the City of Paris: 'Your city is changing to reflect the way you live your life'[138]

[135] http://www.tempsxciutats.org/ca/home [Accessed 30 July 2010]
[136] http://tempoterritorial.free.fr/spip.php?rubrique1 [Accessed 30 July 2010]
[137] Marie de Paris, *The Time Office of the City of Paris,* 2006
[138] Bureau des Temps, 2006, p.4

3.5 Soundscape Design

As explored in Chapter 2, noise pollution is becoming of increasing concern. It is described by the European Environmental Agency as 'one of the most omnipresent pollutants in the world today'[139]. Measures have been predominantly preoccupied with reducing sound levels rather than producing them. We usually try to block out traffic or industrial noise with acoustic barriers. However, there is an emerging trend of electric objects for which we have the opportunity to design the sound.

As Schafer recognized, our soundscape is a reflection of our social practices and plays a great part in forming the characteristic of a place. Cars, for example, have become a part of the urban soundscape and without traffic noise our cities would seem very different. However, the introduction of silent electric cars has the ability to change this. The Institute for Acoustic Research Ircam in Paris is currently addressing the problematic of the silent vehicle, which has obvious consequences on road safety as well as on soundscape aesthetics. For example, a silent approaching vehicle would give unwary pedestrians no warning. Thus sound is critical to the design. However, in order to be effective, designing the sounds for our future roadways must respect the existing soundscape. It involves an in-depth understanding of how we hear and identify environmental sounds, and should consider a combination of factors including sound identifiability, reaction time, and aesthetics.

A recent attempt to 'recompose' the soundscape is *City Symphonies*[140], a sound design project by Mark McKeague, which views the recent introduction of the silent electric car to the urban environment as a potential instrument to the soundscape of the future. McKeague explored how the car's sound can change according to its relationship to other cars and the environment. By increasing the pitch as cars pass by, the complexity of sound changes as cars group together and move part. Essentially articulating the spatio-temporal inter-relationships of this new urban infrastructure, a time-place specific soundscape is generated according to the particular road configuration and traffic flows. Thus in asking the question '*Can the city become a symphony?*', McKeague proposes the roadway as the score.[141]

Last but not least, we draw attention to the recent extension of acoustic design to one addressing all of our senses, including light, smell, touch, and heat. Led by Jean-Paul Thibaud and the International Ambiances Network[142] it encourages the multisensorial understanding of our urban environments and proposes the design of urban 'ambiances' rather than simply physical spaces. It thus poses the question '*How to go from static appraisals of physical environment, to dynamic sensory atmospheres*?'[143]and reinforces the need for a more dynamic, multifaceted approach to urban design.

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[139] http://eyeonearth.org/map/NoiseWatch/ [Accessed Sept 2013]
[140] http://www.creativeapplications.net/maxmsp/city-symphonies-the-future-sound-of-traffic-by-mark-mckeague-di-rca-2012/ [Accessed November 2012]
[141] http://markmckeague.com/work/city-symphonies/, City Symphonies – the future sound of traffic, Mike McKeague [Accessed November 2012]
[142] http://www.ambiances.net, [Accessed Sept 2013]
[143] http://www.ambiances.net/workshops/nantes-2013-simulation-of-ambient-environment.html, [Accessed Sept 2013]

Conclusions: Designing Urban Rhythms

According to Lefebvre, for rhythmic change to occur in society, *'a social group, a class or a caste must intervene by imprinting a rhythm on an era, be it through force or in an insinuating manner'.* [144] We have seen how recent cultural movements and social policies are attempting to resist and manipulate the temporal parameters of urban life. It is also clear how the design of transport infrastructure systems and schedules determine urban rhythms. Often seen as static and thus 'time-less', the role of space in time design is not to be underestimated, as recognized by Crang: *'Seeing time in terms of space is to submit it to the uniformity of a ruling view, to allow its administration.'*[145] In the search for a way to spatially design urban rhythm, in the next chapter we explore the techniques used to represent time in urban design as well as the other related domains.

[144] Lefebvre, 2004, p.14 in Edensor, 2010, p.11
[145] Crang, 2001, p.204

4 Representation of urban rhythms

"Fundamentally, there are two opposite methods of representation. Buildings or environments can be described conceptually or experientially. The conceptual method is abstract; it emphasizes layout and structure. The experiential form of representation explains how environments are perceived by the human senses." [146]

According to urban designer Peter Bosselmann, there are two types of urban representation: conceptual and experiential. One deals with physical parameters such as structure, shape and massing, while the other with experience. The applied practice of urban design requires both. However, the dominance of visual representation techniques more often than not privileges its spatial rather than temporal effects.

The graphic urban masterplan is the principal representation technique in the applied field of urban design and planning. The plan is used for both the analysis and design of the urban environment, as will be explained below by Portzamparc's proposal for Le Grand Pari. Figure 4.1 below presents a series of urban plans representing the existing conditions of the area Bobigny to the north of Paris, namely its transportation infrastructure, built form and activity zoning respectively.

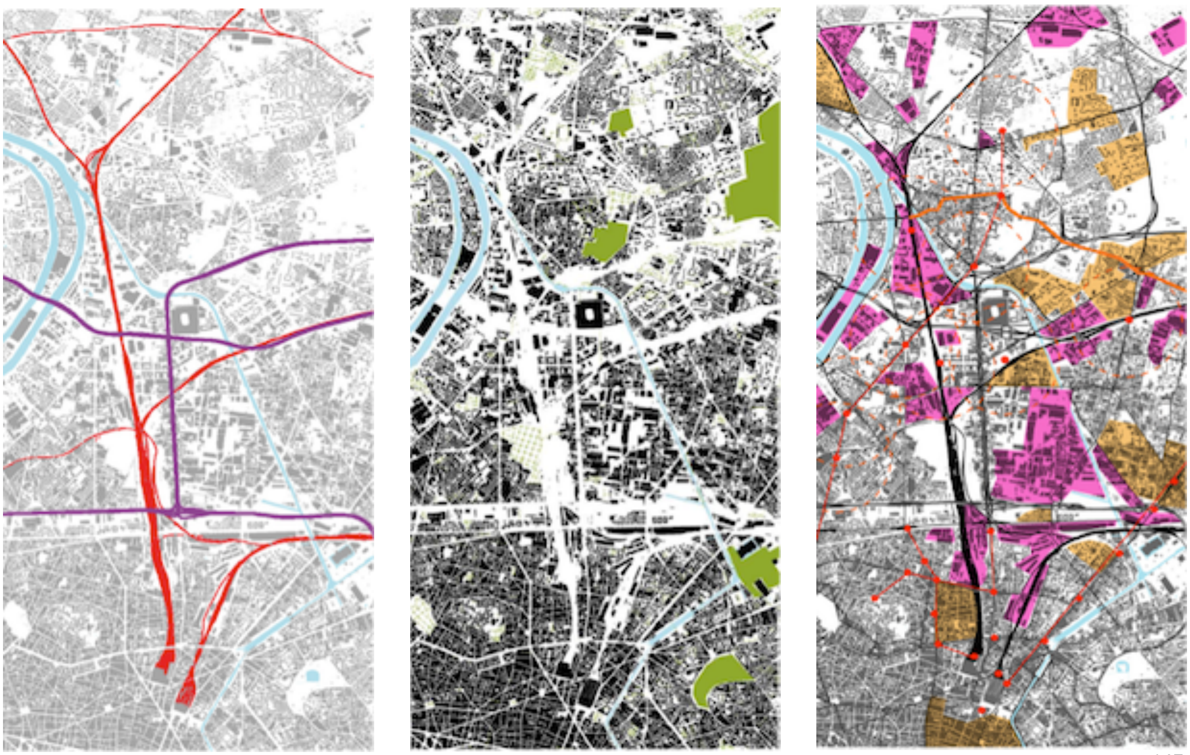

Figure 4.1: Urban plans for Bobigny, Paris : i. Transport; ii. Built form, iii. Activity zones[147]

[146] Bosselmann et al, 1993,
[147] Portzamparc, Le Grand Pari, 2008, pp.184,188, 189

These elements are combined in overall analytical plan in Figure 4.2, in which several spatio-temporal problems are explained in words – bad public transport service, dense neighbourhood, area in high evolution, neighbourhood saturated by the operation of the train stations.

Figure 4.2: Overall diagnostic plan of Bobigny[148]

This poses the question of how we can represent these spatio-temporal urban problems in analysing an existing urban condition.

At the same time, the urban masterplan is also used as a design tool to explore and demonstrate future proposals. While concerned with the organization and design of built objects in space, its effect on the urban system as a whole is inherently temporal. Being inherently static, the traditional urban masterplan thus has its limits in the design of dynamic urban systems. Below in Figure 4.3 is the design proposal of Portzamparc for the same area of Paris. The masterplan is assisted by supplementary 3D drawings and text descriptions on the side in order to explain certain elements which cannot be expressed solely in the plan itself – the creation of a tramway, a multifunctional neighbourhood, and 3D views of reconstructed areas. How then can we design for multidimensional and temporal urban elements such as transport infrastructure, mixed activities, urban morphology and personalised neighbourhoods with such a static, one layered, graphic representation technique?

[148] Ibid., p. 190

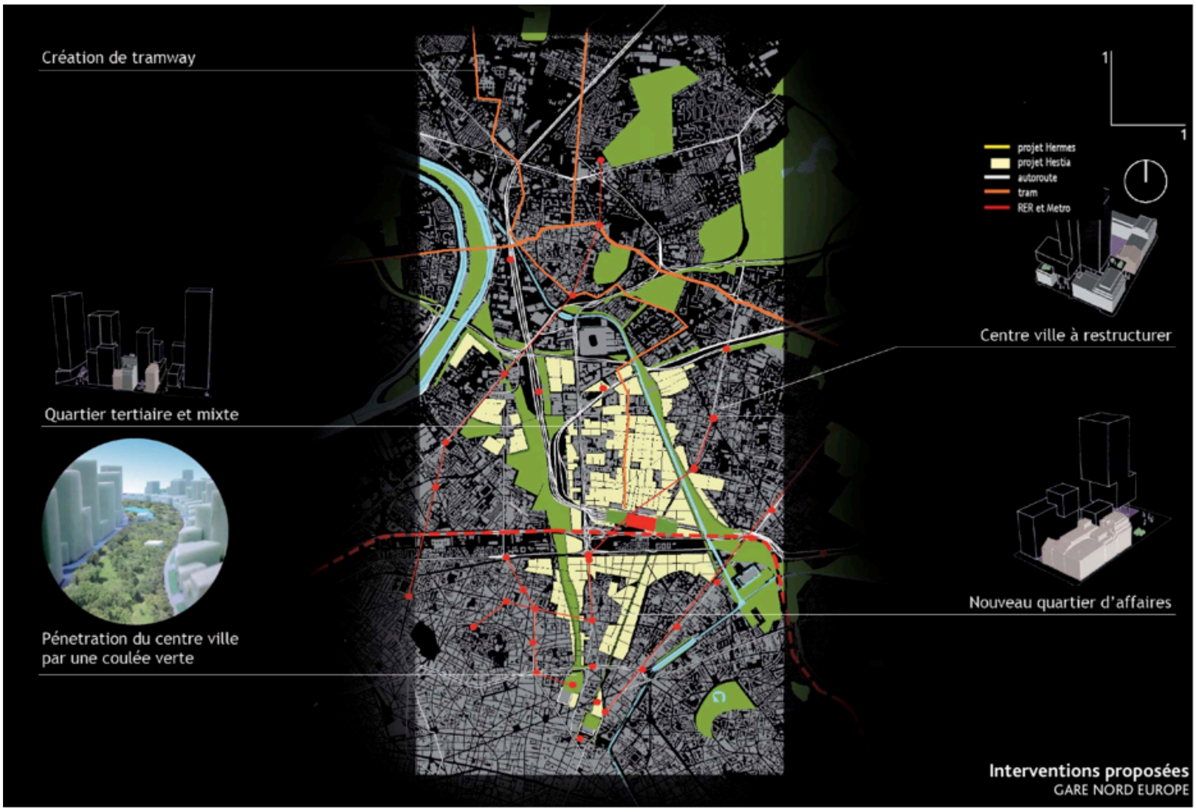

Figure 4.3: Proposed masterplan for Bobigny by Atelier Portzamparc[149]

In our search for a more spatio-temporal urban representation technique, we first explore those previously attempted in urban design and planning, before expanding to those used in Time Geography and Soundscape Studies. We discuss the time-space diagrams of Hägerstrand, the space-time notation of Whyte, 2D and 3D visualisation of urban flows and recent attempts at real-time data representation, as well as the growing development of soundmaps.

4.1 Image of the City

'Throughout the history of the profession, designers have searched for new graphic languages of design. Among the professionals in the field of architecture, engineering, and urban planning, urban designers have searched most actively. Frequently asked to visualize the effects of development over long periods of time, they found their task impossible to perform without the aid of improved visual tools.'[150]

While designers have always relied on abstract representation techniques in their design processes, their ability to represent the quality of the physical urban environment was questioned in the 1960's due to public reaction against large-scale urban renewal projects

[149] Portzamparc, 2008, p.191
[150] Bosselmann et al. 1993, p.10

and increasing freeway development. Through his landmark text *'Image of the City'*[151] Kevin Lynch was to acknowledge the temporal nature of the city and the difficulty in its representation:

'Like a piece of architecture, the city is a construction in space, but one of vast scale, a thing perceived only in the course of long spans of time. City design is therefore a temporal art, but it can rarely use the controlled and limited sequences of other temporal arts like music.'

Lynch was to propose a new graphic language for the representation of the experiential qualities of urban form. The aim of such a language was to better communicate the effect of future urban changes, and thus improve public consultation and the decision-making process.

These principles were applied in *'The View from the Road'* where Lynch, together with Appleyard and Meyer, attempted to develop a notation for the representation of the experience of driving. In order to capture the changing points of view over time, they proposed a new space-sequence notation focusing on issues of orientation and visual form. They developed various graphic representation techniques shown in Figure 4.4 below, from realistic film sequences to a more abstract notation showing the rhythms of visual intensity as a series of lines.[152]

However, Appleyard was to later reflect on the limits of such abstract techniques in the representation of human experience:

'*Even with notation systems that describe experience, as developed in The View from the Road (Appleyard, Lynch, & Myer, 1964), people must have a deep familiarity with the abstract medium and what it represents in order to feel with any assurance that they can predict its experiential reality*.'[153]

Bosselmann was to also acknowledge these limitations, despite its good intentions:

'*Ironically, much of the new graphic imagery invented in the early 1960s was idiosyncratic, relying on notation systems that were difficult, if not impossible, to understand*.'[154]

This is a reminder that in the development of any new representation technique, effective communication should be carefully validated in order to ensure relevance.

[151] Lynch, K., *The Image of the City*, MIT Press, Cambridge, MA, 1960
[152] Appleyard, D., Lynch, K., and Myer, J.R., *The View from the Road*, MIT Press, Cambridge MA 1964
[153] Appleyard, D., 'Understanding Professional Media.' In *Human Behavior and Environment,* Altman and Wohlwill, (eds.), Vol. 2, New York, Plenum Press, 1977
[154] Appleyard, 1977. in Bosselmann et al., 1993, p.11

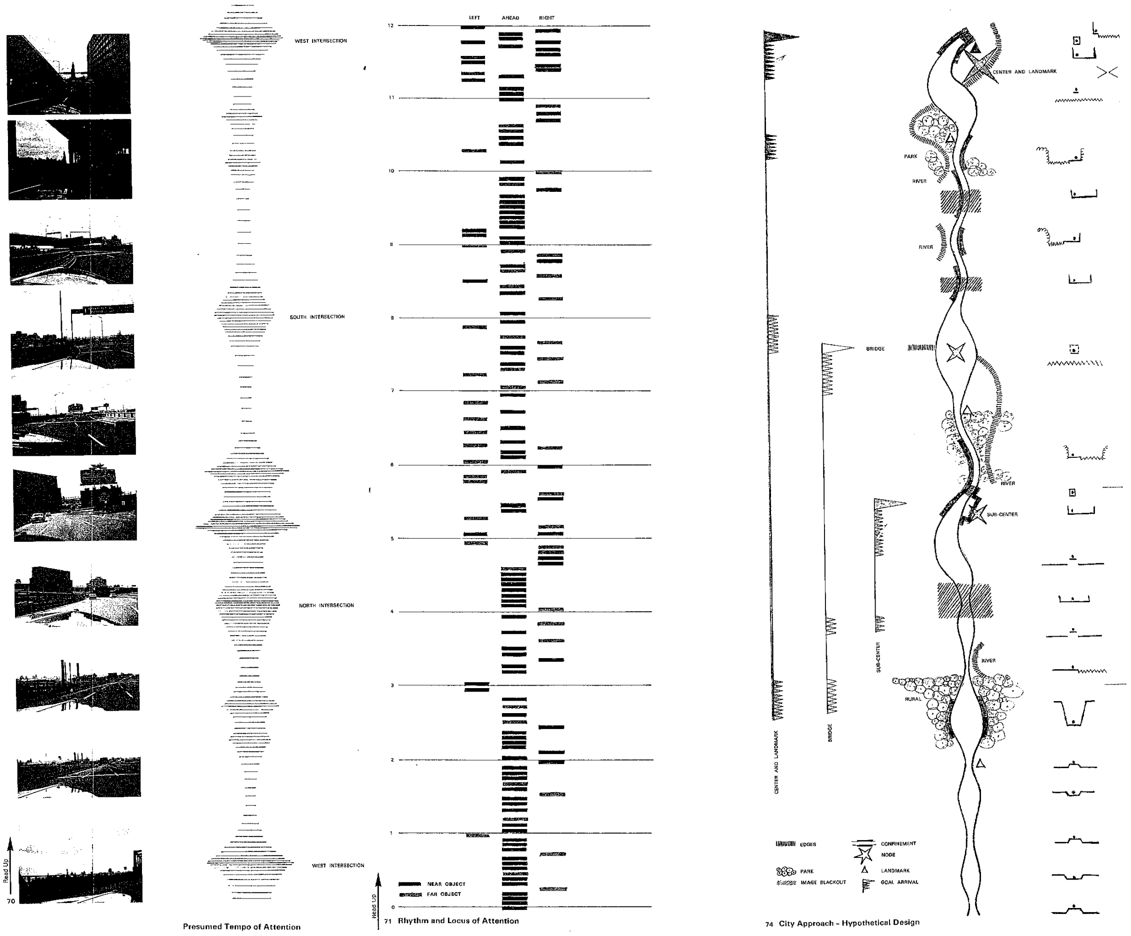

Figure 4.4: (a) Film Sequence (b) Tempo of attention (c) Rhythm and locus of attention (d) Space-motion diagram [155]

4.2 Space-Time Geography diagrams

For Time Geography, primarily concerned with the 'mappable', the representation of time is critical to its analysis. However, to do so it had to surpass the limitations of the traditional map, whose representation was limited to '*one moment frozen in time, as a static snapshot*'[156]. In the early 1970's, four objectives were outlined for the development of a system of representation in Time Geography:

1. It should be easy to realize what the representation corresponds to in the reality
2. The representation should have a wide scope of applicability.
3. The representation should have the ability to generate questions which one could not pose without it.
4. The representation should admit conclusions and calculations whose correspondence with reality does not have to be verified by observations.[157]

155 Appleyard, D., Lynch, K., and Myer, J.R., *The View from the Road*, MIT Press, Cambridge MA 1964
156 Gren, 'Time-geography Matters', in May& Thrift, 2001, p.210
157 Gren, 2001, p.210

In his attempt to transcend *'the flat map with its static patterns'* Hägerstrand developed his now well-known 'time-geographic diagrams'. His inclusion of a vertical time axis over the mapping of space allowed the representation of the movement of a body in space over time.[158] The diagram of Figure 4.5 represents a space-time path starting from home, going to work and returning back home. The 'bundle' indicates the meeting of several space-time paths, while the single line represents a phone call, which exists only in time and not space.

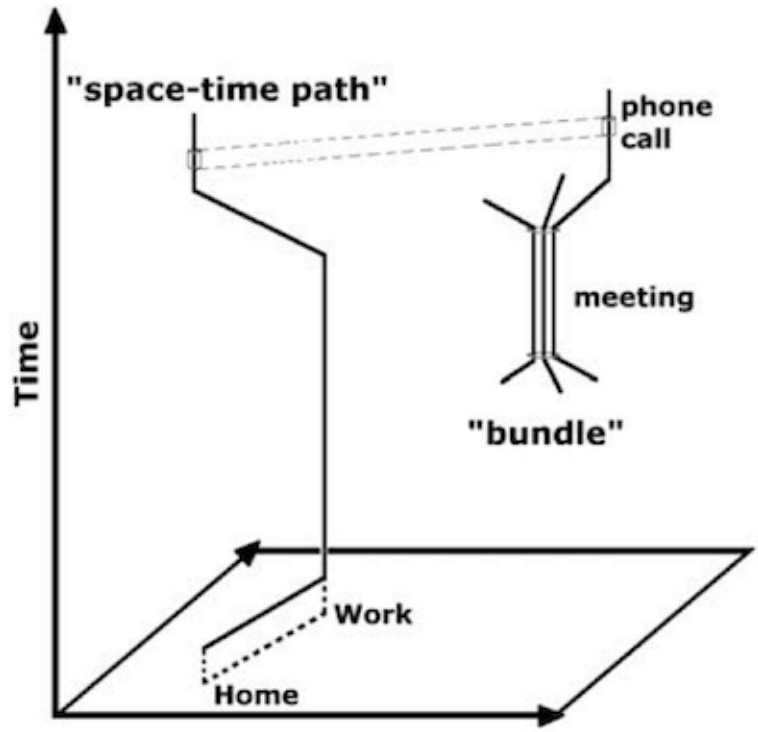

Figure 4.5: Time-space diagram, Hägerstrand [159]

Consisting of time plotted against space, it represented the human body as a trajectory, mapping both its physical location and movement. To a degree, it allows the simultaneous representation of temporal and spatial information, useful for identifying spatio-temporal patterns.[160] However, being a 2D representation of a 3D visualization, there are limits to the amount of information it can represent. There is a legible limit to the number of paths and timespans that can be represented.

[158] Ibid.

[159]Vrotsou et.al., *2D and 3D Representations for Feature Recognition in Time Geographical Diary Data*, Information Visualization 2010, v. 9, p.275

[160] Kristensson et.al, *An Evaluation of Space Time Cube Representation of Spatiotemporal Patterns*. IEEE Transactions on visualization and computer graphics, 2009, 14/4

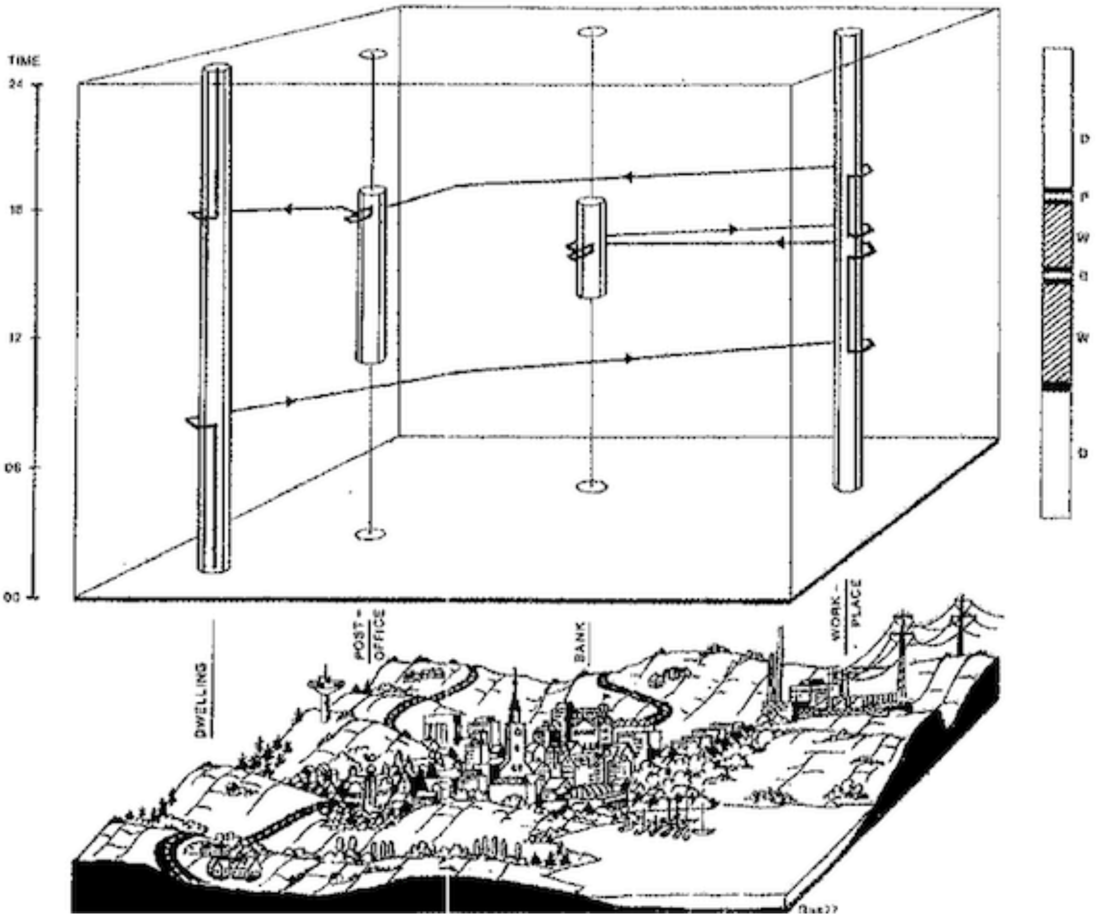

Figure 4.6: Daily temporal organization, School of Lund [161]

Contemporary representation techniques have continued along the lines of Hägerstand's time-space diagram (Figure 4.6), plotting the spatial path in the two-dimensional plane and time in the vertical dimension. Both the *SpaceTimeCube* [162] used by Kristensson et.al. (2004) and the *Space-time aquarium*[163] by Kwan (2004) are examples. However, they have been criticised for remaining theoretical and abstract, and thus relatively unused.[164]

Another version of this form of representation, incorporating the element of probability, is the *Cone-Of-Possibility Constraints,* shown in Figure 4.7. Indicating the spatial limits placed on the movement of an individual due to external factors, the resulting 'cone' thus represents the area which is potentially accessible.[165]

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[161] Image by urbanTick / Taken from Lentrop, 'A Time-Geographic Simulation Model of Individual Activity Programmes', in Carlstein, *Timing Space, Spacing Time*, 1978. [Accessed September 2012]
[162] Ibid.
[163] Kwan, M.P., Lee, L., Geovisualization of Human Activity Patterns Using 3D GIS. A time-Geographic Approach. in Goodchild MF Janelle DG *Spatially integrated social science*, Oxford University Press, 2004, p.48-66
[164] Neuhoff, 2010, http://urbantick.blogspot.fr/search/label/aquarium [Accessed September 2012]
[165] Hägerstrand, T., 'Space, time and human conditions'. in Karlqvist A. et al. (ed.) *Dynamic allocation of urban space*, Saxon House Lexington Book, Lexington, 1975

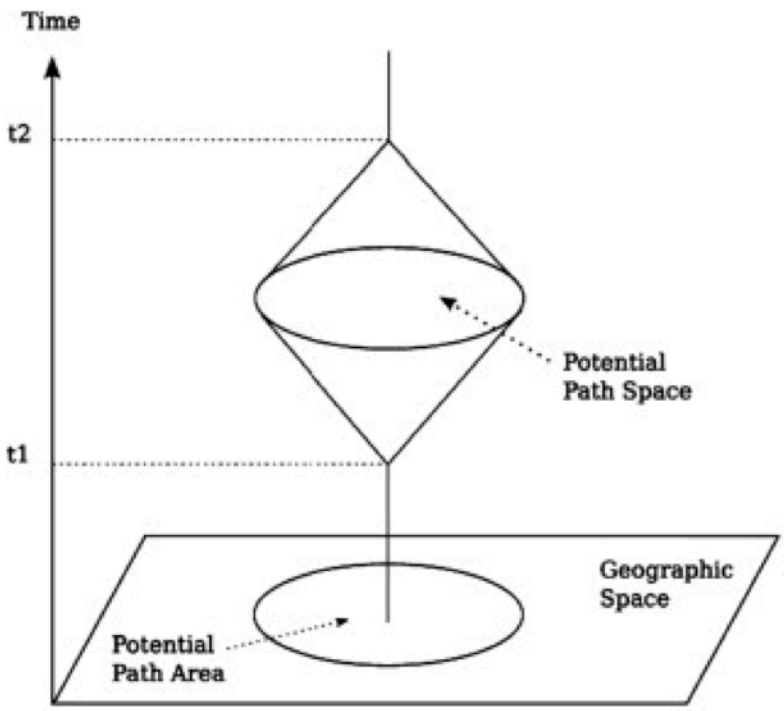


Figure 4.7: Cone-Of-Possibility Constraints [166]

However, the problem with Hägerstrand's 'objective' representation of time as a single line in a single timespace is that a) it does not acknowledge the existence of multiple timespaces, and b) it fails to address the corporeality of the human body and its experience as seen from its own personal timespace.

Thus, such space-time diagrams have been criticised for not adequately representing '*the variety of different physical ontologies that exist in the corporeal world.'* [167] As will be discussed further on, the communication of corporeality in Time-Geography is yet to be resolved.[168]

4.2 Urban Space-Time Notation

The graphic notation of spatio-temporal observations has been often used in order to record pedestrian behaviour in an urban space over time. It was a technique applied by urban designer William Whyte to understand the use of the plaza of the Seagram building in New York. In the image below, we can see the building's northern ledge sub-divided into 11 sections, and the act of sitting represented by a horizontal line. Mapping was performed over a period of 6 hours from 9am to 3pm, and both seating position and duration could be observed. A graph of the accumulated activity over time then revealed the pattern of usage over the day, as seen in Figure 4.8. [169]

[166] Raubal, M. et al., 'Time geography for ad-hoc shared-ride trip planning in mobile geosensor networks', in SPRS Journal of Photogrammetry and Remote Sensing, v.62/5, October 2007, p.366-381
[167] Gren, 2001, p.214
[168] Ibid., p.215
[169] Porta, S., *Dancing Streets. Scena pubblica urbana e vita sociale*, Unicopli, Milano, 2002, p.145

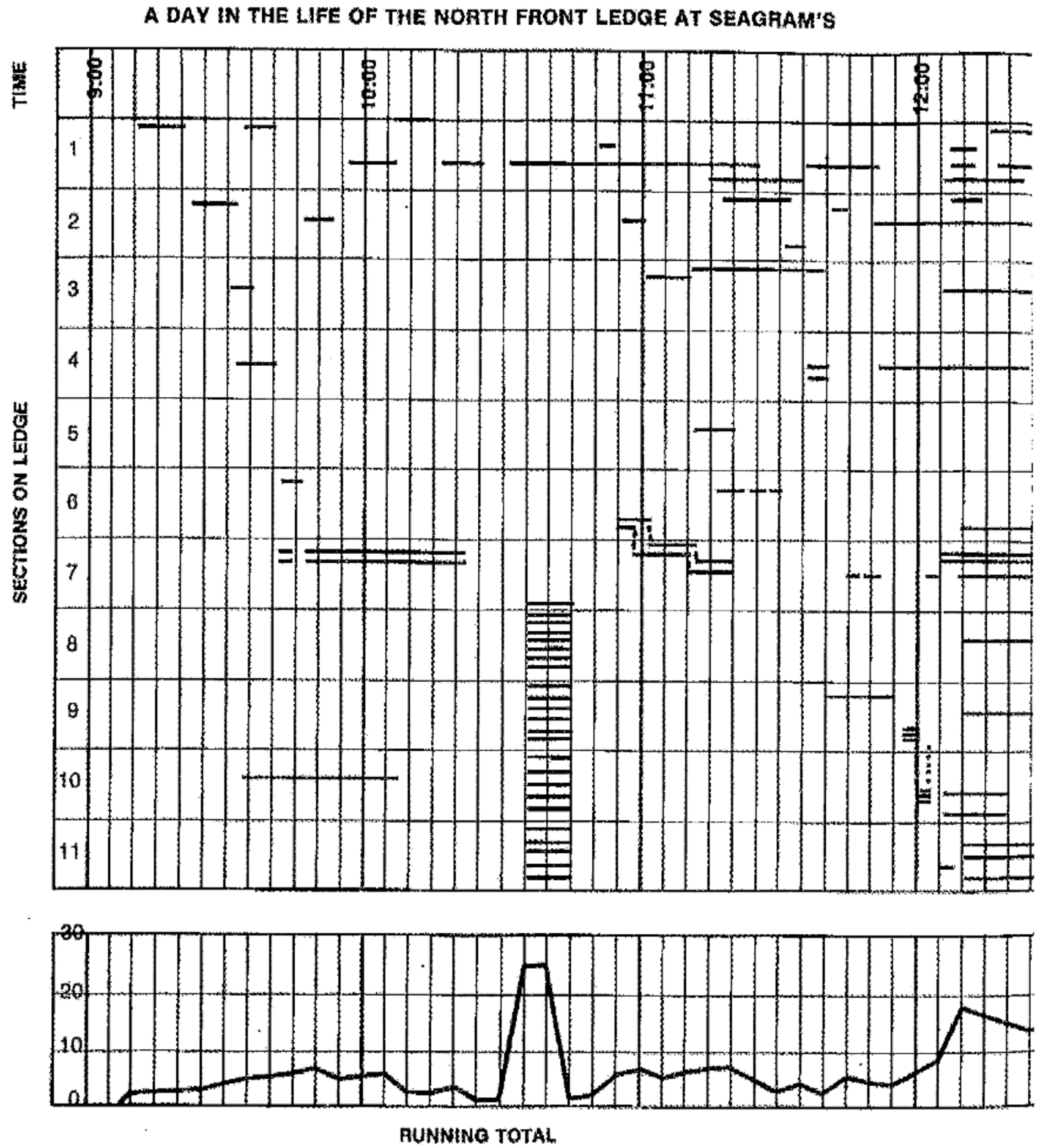


Figure 4.8: William Whyte, Ledge Chart of the Seagram Plaza, NY, 1980[170]

In fact, Whyte was to note the 'musical' nature of these urban movements in his book '*Social Life of Small Urban Places*' (1980):

'Since the Seagram's chart looked so like a player-piano roll, I wondered what the sound would be if all the dots and dashes could be played. A composer friend was fascinated: with the right tonal scale, he said, the roll could be orchestrated and it would be music. I hope one day it will be: A Day in the Life of the North Front Ledge at Seagram's, Adagio.'[171]

The ability to represent such urban rhythms allows us to better understand the use of public urban space and can then be used to inform future urban design decisions.

[170] Whyte, W.H., *The Social Life of Small Urban Spaces*, Project for Public Spaces Inc, US, 1980
[171] Ibid., p.70-71

4.4 Computer-aided visualization

Spatial data visualization has greatly benefited from advances in technology concerning the collection and representation of data. These range from 2D animated maps to 3D visualisations.

2D animated maps are a common technique to represent the change in an urban data flow in a given place. For example, the following online *Bike Share Map*[172] of Paris (Figure 4.9) developed at UCL's CASA visualizes the movement of bike share users by showing the number of bikes at each bike station over time. Here, each docking station being represented as a circle of a certain diameter and colour, either the number of bikes or the number of available docking spaces can be selected for representation. The larger and redder the circle, the greater the number of bikes. Animated over time, one can observe user inflow and outflow of each station as a shrinking or growing circle.

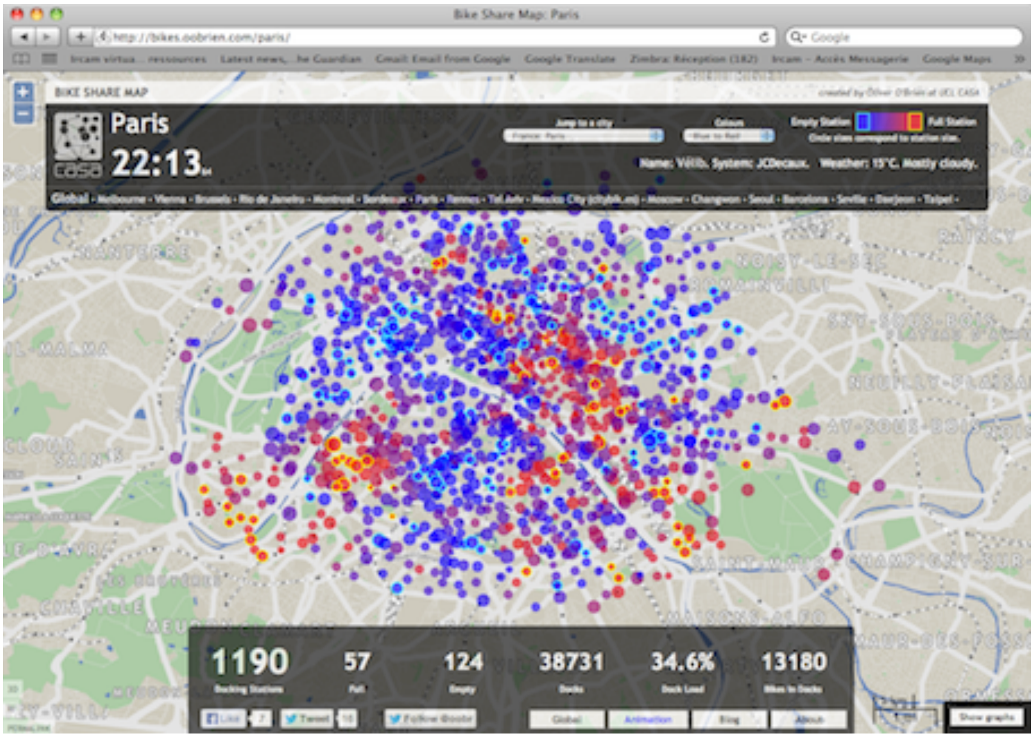


Figure 4.9: Bike Share Map of Paris, showing the fluctuation of bike numbers at each docking station as pulsating circles of changing size and colour.[173]

3D animation has been explored as a visualization technique particularly in the representation of transport infrastructure utilisation for more 'space-time' sensitive planning. In the objective analysis of the Vienna subway below, both population flows and subway utilisation were animated over a 24-hour period in order to understand the use of public transport relative to the city's population distribution. The aim was to better understand the actual usage and the needs of the city's subway system. The population

[172] http://bikes.oobrien.com/paris/ [Accessed Sept 2013]
[173] http://spatialanalysis.co.uk/2011/01/boris-bikesbarclays-cycle-hire-average-journey-times/ [Accessed February 2013]

distribution (Figure 4.10a) and the subway utilisation (Figure 4.10b) were modelled separately, as a 3D mesh or line respectively, with the amount of usage indicated by the extrapolation of each point on a mesh or line on the vertical axis. The two were then overlaid to indicate the interrelationship between population and transport usage over space and time.[174]

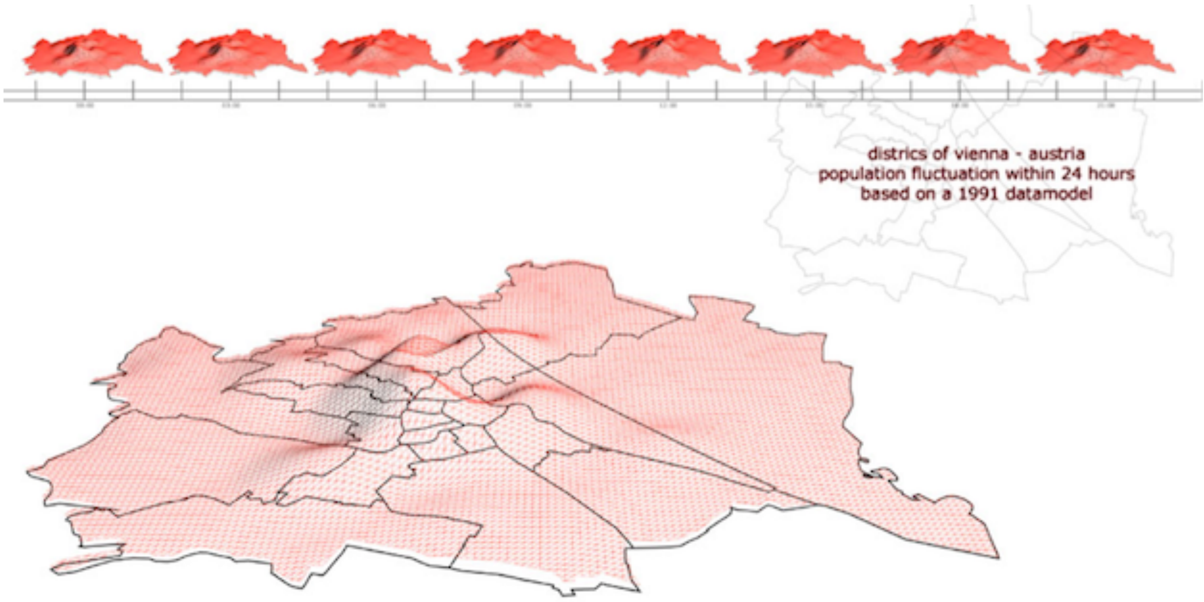


Figure 4.10a: 3D mesh modelling of population fluctuation in Vienna over a 24 hour period [175]

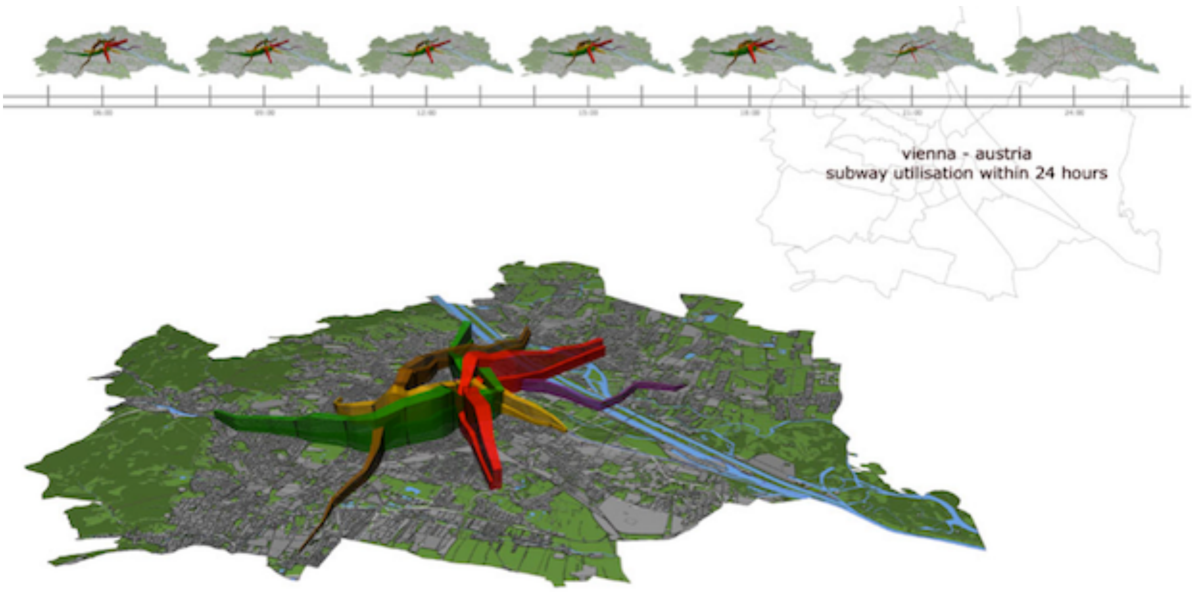
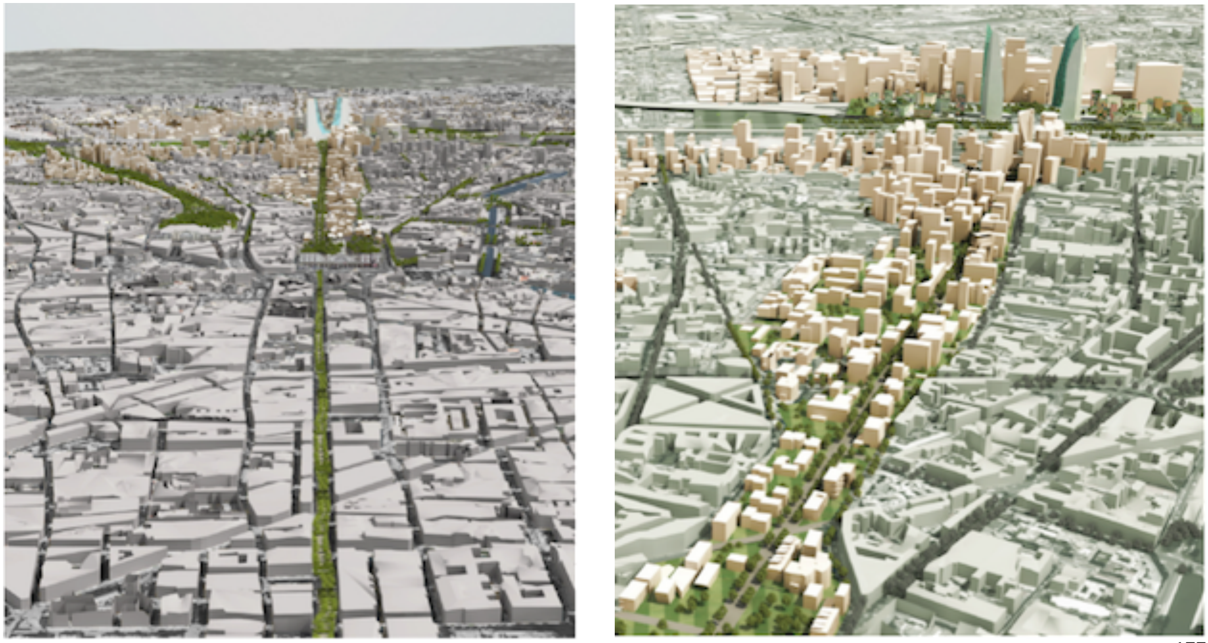


Figure 4.10b: 3D line-extrapolation modelling of Subway Utilisation, Vienna, over 24 hours[176]

[174] Faller, A., *Visualisierungsansätze für Stadtrhythmen,* Fakultät Für Architektur Und Raumplanung Technische Universität Wien, Vienna, 2001
[175] Faller, 2001
[176] Ibid.

On a more subjective level, 'fly-over' animations moving over 3D urban models are becoming increasingly utilised to demonstrate to the client or community how a future design proposal may look like. However, scale and speed are easily distorted relative to the point of view of the camera, and it is also difficult to include the layers of analytical information. One example is the 3D model of the area of Paris analysed previously and shown in Figure 4.11 below. The focus of the image of images is the extension of the central street Boulevard Sebastopol, however, it is difficult to get a sense of scale from the bird's eye perspective of what the rhythm of this transport corridor will actually be like.



Figures 4.11: 3D overhead views of the proposed extension of Boulevard Sebastopol, Paris [177]

Last but not least, real-time visualisations of urban flows are now possible, providing a new level of interaction with the urban rhythm as it evolves. According to MIT's SENSEable city lab, *"Observing the real-time city becomes a means to understanding the present and anticipating the future of urban environments."*[178] The *WikiCity Rome*[179] project, as an extension of the previously described *Real Time Rome* project, attempts to visualise this information in such a way as to promote active participation in real-time. A 'dynamic map' was generated which could be used interactively by its citizens during the 'Notte Bianca' (white night event) in Rome on 8 September 2007. The visualization shown in Figure 4.12 is a 'color flickering overlay'[180] over a map of Rome, allowing one to see the movement of users between events in the city. The position of the user is indicated with an X on the map below. The position of two other people of interest is also shown, as 2 different coloured figures. The yellow trajectories indicate bus movements while mobile phone usage is shown as a shade of blue overlaying the map – the lighter the blue, the greater the usage. Furthermore, current events appear along a timeline below and on the map in real time, allowing users to see what is happening and where, as well as how to get there. Through this real-time urban

[177] Portzamparc, 2008, pp. 198, 194
[178] http://senseable.mit.edu/realtimerome/ [Accessed August 2012]
[179] http://senseable.mit.edu/wikicity/rome/# [Accessed August 2012]
[180] Ibid.

representation, the citizens of Rome were able to consciously participate in the urban dynamic surrounding this event. In the future, such real-time data visualisation has the ability to inform personal everyday decision-making, as well as control the overall rhythm of the city concerned.

Such real-time mappings can perhaps be seen as the closest space-time representations to being at once both inside a rhythm and outside of it. As stated by the SENSEable City Lab, real-time representations allow us to '*interact with the current urban dynamic and help change it to improve urban sustainability.*'[181] However, the amount of data represented simultaneously can be seen as problematic for our visual comprehension. We are left asking the question of how we can avoid overloading the visual senses when both the physical and digital environments are simultaneously competing for our attention.

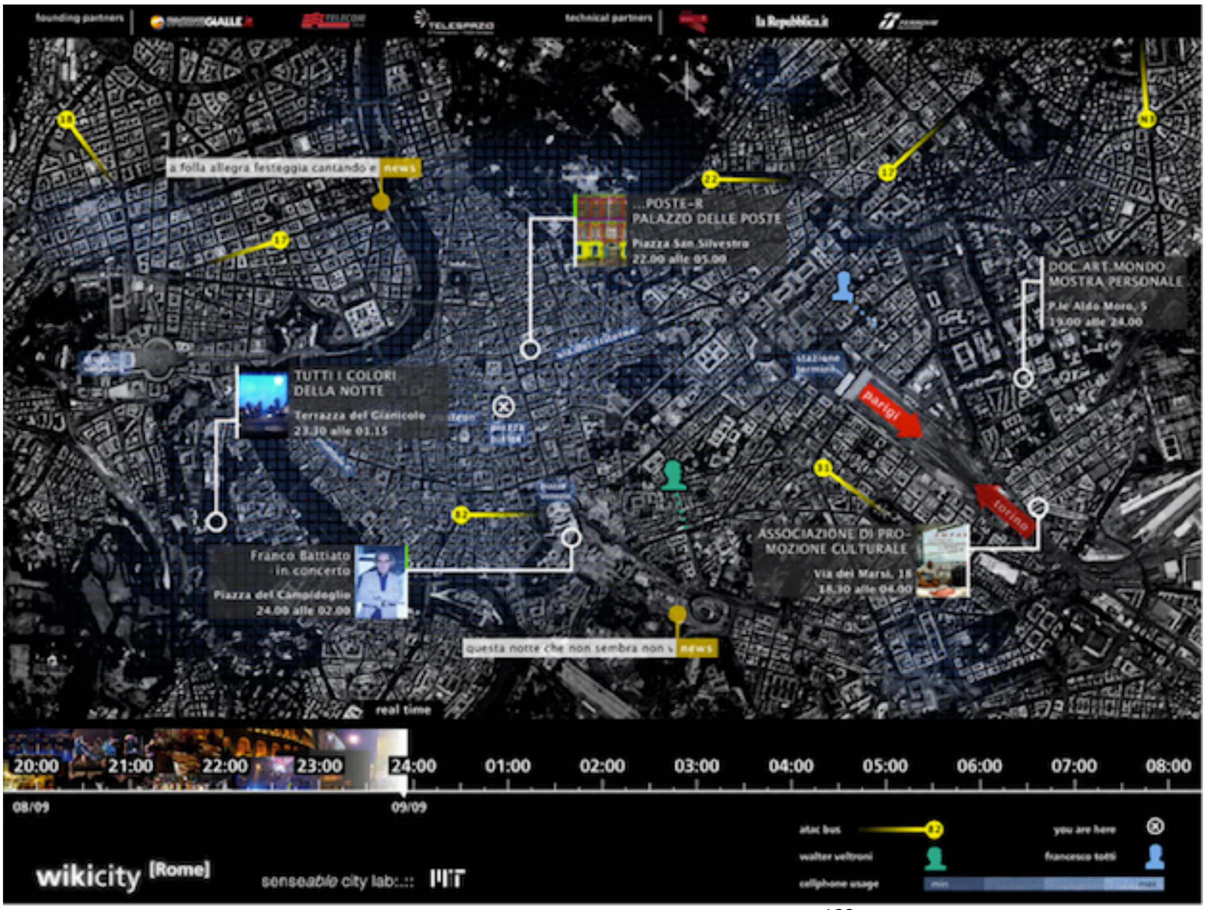


Figure 4.12: Wikicity Rome Interface[182]

[181] http://senseable.mit.edu/realtimerome/ [Accessed August 2012]
[182] http://senseable.mit.edu/wikicity/rome/images.html [Accessed August 2012]

4.5 Soundmaps

In our search to ease the demands of visualisation, we explore the relatively recent addition of the sonic element to urban representation. Soundmaps, as the name suggests, involves the integration of sound in the traditional geographic map. The collaborative uploading of environmental sound recordings has been occurring since the launch of Freesound.org by the Universitat Pompeu Fabra. Their recent integration with online mapping technologies, notably Google Earth, has allowed us to link these recordings with their geographic location and allowing us to better understand our acoustic environments.

The rising popularity of soundmaps is perhaps indicative of their effectiveness, with soundmaps being created for a number of cities around the world. Creative interactive online applications, such as the Soundcities project (Figure 4.13) in which users are able to recompose the soundscape, are helping to promote both an awareness and an appreciation of the acoustic qualities of soundscape.

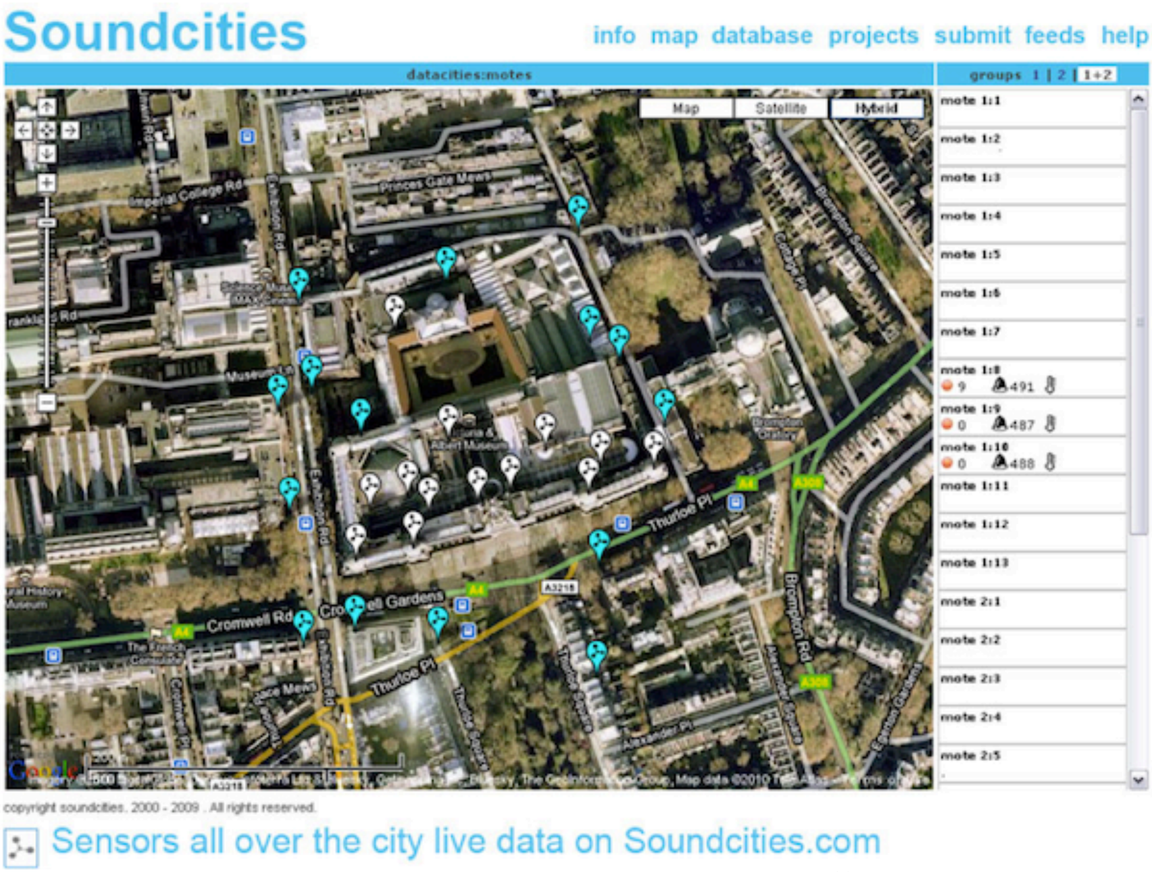


Figure 4.13: 'Soundcities' Project, Stanza[183]

The UrbanRemix[184] project of Georgia Tech promotes collaborative soundmapping through a mobile application for recording soundscapes and integrating them into a shared database. The sounds can then be browsed and remixed by drawing a path over the online map to render the result, as shown in Figure 4.14 below.

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183 Stanza, http://www.soundcities.com/va/, [Accessed March 2010]
184 http://urbanremix.gatech.edu/ [Accessed May 2013]

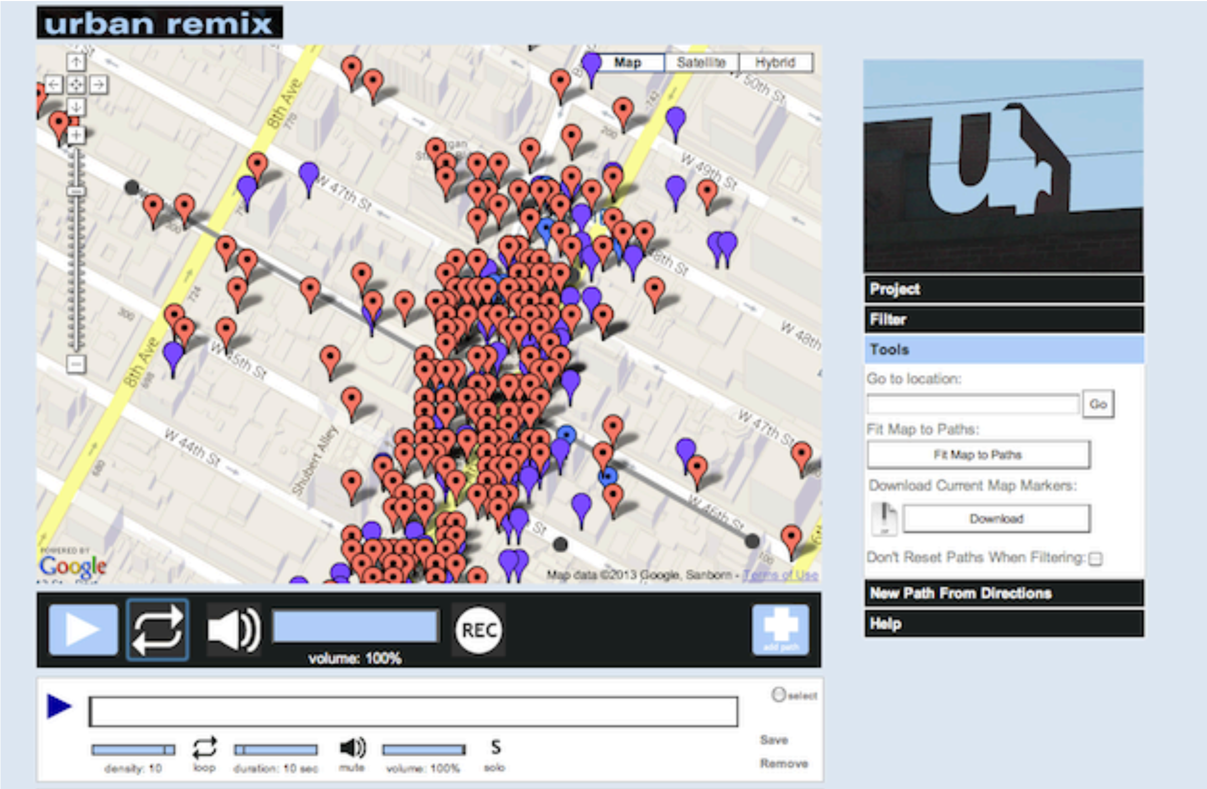

Figure 4.14: The UrbanRemix interface for listening to recorded sounds along a path [185]

Perhaps the most comprehensive soundmap initiative to date is NYU's Citygram proposal for a city-wide, geolocalised recording of the soundscape in real-time. Through the deployment of large-scale remote sensing networks throughout the metropolitan area, the intention is to capture, analyse, classify, retrieve, and visualize the spatio-acoustic properties of the city. This raises questions of privacy and censorship, due to the recording of private conversations for example. However, it will also allow us to monitor urban rhythms in greater detail and over longer periods of time.

[185] http://urbanremix.gatech.edu:8080/urbanremix-webapp/?projectid=2645 [Accessed Sept 2013]

Conclusions: Issues of spatio-temporal representation

'Time is an experience of flow rather than being a series of static images enchained in a sequence. The criticism about models of space and time thus works not only at the level of experience but also that of representation. We need a sense of the event and process of time, rather than letting thinking be dominated by static representations.' [186]

Crang

Of the various mapping techniques demonstrated, the notion of an 'objective representation' itself and the imposition of a single 'time-space frame of reference' from the external point of view of one observer, is contradictory in itself. They can in general be criticised for their simplistic implication of a 'singular abstract temporality', representing the *'timespace of an outside external Observer'* and ignoring the fact that *'human beings will experience themselves and their environments from different points'*. [187]

Time-geography has been 'admired for its representational potentiality and for offering a solid conceptual and methodological departure for empirical research'[188]. However, it is yet to achieve the representation of the multiple time-spaces that corporeality demands. The line lacks corporeality, presenting *'individual rhythms as rather unsensual and disembodied.'*[189]

Ideally, 'every trajectory should in fact be placed in its own timespace contexts, and represented in such a way.' To achieve this as an observer of a time-geographic diagram, we are obliged to 'place ourselves *inside the line of each trajectory* instead of observing them from the outside in relation to the coordinates of time and space signified in the diagram.'[190]

The problem, as recognized by Deleuze, is that *'movement (time) is different from distance covered which as a line may be infinitely divided (space)'*.[191] Thus movement, unlike space, *'cannot be divided without changing qualitatively each time it is divided.'*[192] This requires time to be considered as *intrinsic* to the movement, rather than just an external measure. [193]

In the search for the representation of a more dynamic space-time, Deleuze calls for *'representations that within them encode the forces and movement of time'*.[194] However, rather than simply striving for a more 'realistic' representation to be observed externally, what is needed is the representation of corporeality through the experience of a *'corporeal activity'* itself.[195]

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[186] Crang, 2001, p.206
[187] Gren, 2001, p211
[188] Ibid., p.209
[189] Mels in Tim Edensor, 2010, p.1
[190] Gren, 2001, p.212
[191] Deleuze (1991) in Crang, 2001, p.206
[192] Deleuze (1986:1) in Crang, 2001, p.206
[193] Deleuze (1991) in Crang, 2001, p.207
[194] Ibid., p.206
[195] Gren, 2001, p.212

In the applied field of urban design, Bosselmann was to also call for a more 'experiential form of representation' towards the more effective communication of urban design projects:

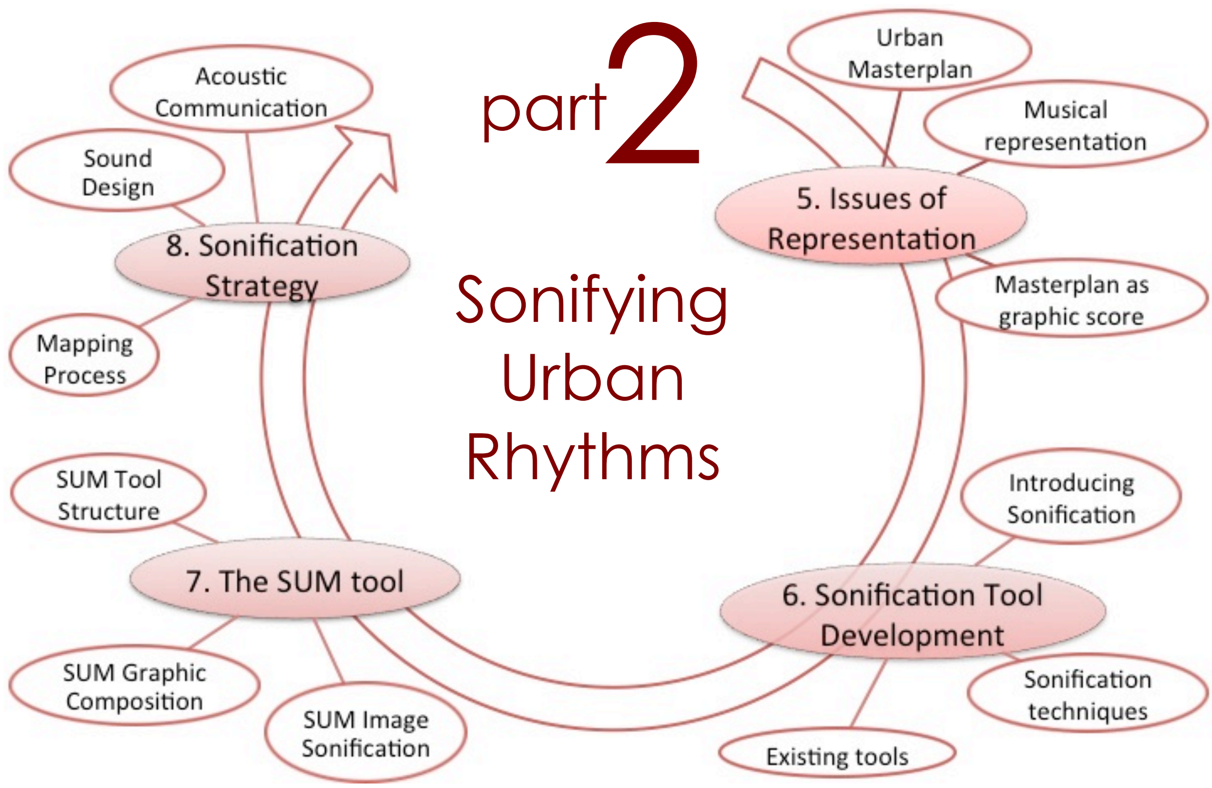
'Few people outside the design and engineering field can read two-dimensional drawings and understand what it would be like to walk alongside a building thus shown. The general public understands the experiential form of representations.'[196]

Furthermore, he was to recognize the need for such representation techniques for the use of the Architect or Urban designer in the design process itself.

'The mental image of a design is only partially expressed by such graphics. Fewer and less exact graphic conventions exist for expressing the experience of design ideas.'[197]

Taking the lead of a more sensory approach to urban design, as promoted by such movements as the International Ambiances Network, we look towards alternative modes of urban representation. As noted by the New York Society for Acoustic Ecology and its NYSoundmap project, *'While acknowledging that the visual sense often dominates, and conscious of the fact that the internet is largely a visual interface, we strive to create spaces that engage ALL the senses, and the mind, in a truly interactive way.'*[198] Of all the other senses complementary to vision - sound, smell, touch and taste – sound has the potential to 'animate' a map through its inherent temporal properties. In addition to the representation of acoustic quality, a soundmap can also allow us to experience our urban environment in space and time. In effect, the soundmap can be seen as the digital manifestation of Soundscape Studies and Time Geography. Thus in the next section, we explore the potential of sound to embody temporal movement in the graphical line, addressing both the issue of corporeality and the '*subjective character of objectivity*' in current spatio-temporal representation techniques.[199]

[196] Bosselmann et al., 1993, p.10
[197] ibid.
[198] http://www.soundseeker.org/ [Accessed Sept 2013]
[199] Gren, 2001, p.212



Introduction

In Part 2, we attempt to 'capture' the urban rhythms identified in Part 1. We explore the issues associated with the current urban representation technique of the graphic masterplan: lack of temporality; problems of legibility; and the synthesis of multiple sets of data. In order to address these issues, we turn to the temporal domain of music and its graphic representation technique of the score. Building upon previously identified parallels between the musical score and the architectural or urban plan, we propose the masterplan as an open, graphic musical score.

In order to 'play' this masterplan, we utilise the audio communication technique of sonification: the systematic translation of data into sound, in this case image data. In collaboration with Dr. Mika Kuuskankare, a developer of the PWGL visual computer-aided composition environment, we develop the 'Sonified Urban Masterplan' (SUM) tool within the PWGL environment.[200]The aim is an image sonification and graphical computer-aided composition tool, which is both multi-dimensional and spatio-temporal. The result is essentially an audio-visual tool-kit for both the representation and design of urban plans.

We then develop a sonification strategy, in order to translate the graphic parameters of the urban masterplan into sound parameters. We explore the various existing sonification techniques, towards the effective sonic representation of the urban environment. Using a variety of sound synthesis techniques, we develop a set of 'Urban Instruments' for the mapping of each urban element of interest: transport; urban form; activity; and urban design. The resulting Urban Sonic Code will be applied to our case-study city of Paris in Part 3.

[200] Software implementation by Dr.Mika Kuuskankare during a period of collaboration at IRCAM, Paris, 2011

5 Towards a 'Sonified' Urban Masterplan

'to capture a rhythm one needs to have been captured by it. One has to let go, give and abandon oneself to its duration. Just as in music … one must be at the same time both inside and out.'[201]

In the field of urban planning, which must compose a number of urban flows in space as well as time, a spatio-temporal representation technique is required. In urban design, which seeks to compose human experience, the embodiment of corporeality is also desirable. As discussed in the previous section, graphic techniques used in architecture and urban design, as well as those used in Time-Geography, have their phenomenological limits, raising the question of whether temporality is '*resistant to representation'*.[202]

Due to its inherently temporal nature, sound is well adapted to the representation of rhythm. Furthermore, it has with the potential to reconcile the corporeal with the mappable. As observed by Lefebvre, in order to grasp a rhythm, one must '*let oneself go…abandon oneself to its duration*'. However, in order to analyse it, a *'certain exteriority enables the analytic intellect to function'*[203]*.* Music, as suggested by Lefebvre, allows one to be both 'inside and outside' a rhythm, so that we can be both participant and observer. Thus we propose sound as an appropriate used to both represent rhythm, as well as experience it corporeally.

This connection between music and urban experience has been drawn by a number of architects and urban designers, growing from Goethe's analogy of architecture as 'frozen music'. While most exploration of this have focused on the architectural object itself, landscape architect Hanoch-Roe, was to propose the musical score in the 'scoring' of urban experience as a whole, and the creation of a more 'fluid' urban design.

Thus in this section we explore the use of the graphic score in the representation of urban design. We seek to translate the graphic space of the urban masterplan into the temporal space of music, and express these spatio-temporal relationships in sound. In this way, we hope to capture the rhythms identified by Lefebvre, and hear what Crang described as *'the music made by diverse beats forming the experience of place.'*[204]

[201] Lefebvre, 1995, p.219, in Crang, 2001, p.200
[202] Quick, 1998, p.65-6, in Crang, 2001, p.200
[203] Lefebvre, 1995, p.219, in Crang, 2001, p.27
[204] Crang, 2001, p.192

5.1 Limits of the Urban Masterplan

As previously explained in Part 1, the urban masterplan is the main representation technique for urban design and planning, for both professionals and their communication to the general public. Occupied with space, its representation has traditionally relied on graphical means to represent the composition of urban structural elements such as roads, buildings and vegetation. However, this static technique has its limitations in representing their temporal composition, which determines both urban experience and the overall urban dynamic.

In addition to representing urban structural elements, a masterplan can also be used to represent their attributes, such as height, function and density. Thus a large quantity of overlapping information must be simultaneously represented. However, the representation of the complexity of urban data on the one map is also constrained for obvious legibility reasons. Thus the data is often separated into individual maps. For example, Figure 5.1 shows two different data attributes of the same structural element: building height and building function; which would otherwise be difficult to represent on the one map without one map concealing the other.[205]

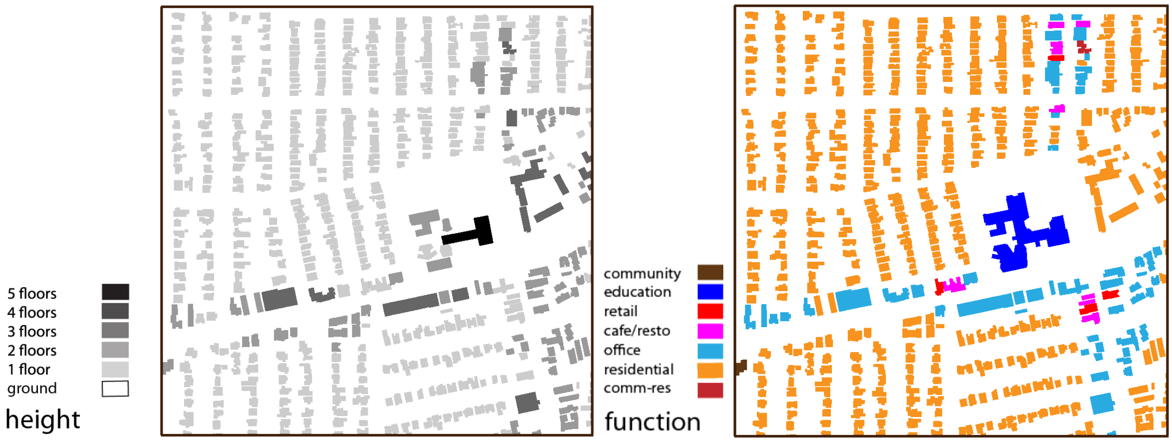


Figure 5.1: Two different attributes of the same structural element: building height and building function

Finally, there is often the need, in the analysis of complex urban systems, to synthesise multiple layers of graphic information simultaneously. The problem of multiple image layers is not only in their visualization but also in their comprehension. With current analytical techniques such as Multi-Criteria Evaluation, in which the data of all the layers is weighted before being combined into one synthesized layer, the identity of each layer is lost. By overlaying them, in space as well as time, we hope to be able to hear the relationships between each layer while maintaining their individual identity. After all, a system is more than the sum of its parts.

Thus in the following section we will explore how can we simultaneously represent the relationship between multiple layers of information, in order to analyse and design for them both in space as well as time.

[205] Ibid.

5.2 Musical representation techniques

'Architecture and music both rely on numerical proportions, music measured in time and architecture in space. One can argue that architecture may be conceived as 'frozen music,' and the spatial construction of architecture utilizes temporal procedures in the process of deciphering the tension between all its simultaneous elements over time.'[206]

Hanoch-Roe

The intersection between music and architecture has long been explored for commonalities in its organisation of space and time. While music is 'measured' in time and architecture in terms of space, both rely on numerical proportions. In fact, architecture has often been described as 'frozen music', as previously explained.

However, the intersection between their graphic representation techniques is much less explored. Yet the two techniques must organise and represent the same rhythmic qualities: pulse; tempo; acceleration and deceleration; density of texture or instrumentation; and formal organization. This led Hanoch-Roe to propose the potential of the musical score in urban design, with the objective of creating a more 'fluid' urban design[207].

Thus, in our search for a spatio-temporal representation technique for urban design and planning, we explore how musical representation techniques can help 'give time' to the static, graphic space of the urban masterplan.

5.2.1 The Conventional Musical Score

'each conventional score has a graphic dimension, which may indicate, without necessity of prior knowledge, aspects such as regularity of pulse, relative tempo, acceleration and deceleration of the pace, density of texture or instrumentation, and formal organization. Such terms also relate to architectural plans, which incorporate ideas of spatial pulsation, density of textures and inner pace.'

Hanoch-Roe[208]

The conventional musical score involves the graphical notation of the organisation of sound in time using traditional western music notation techniques, and in doing so determines rhythmic characteristics which apply to both architecture and music.

The term score refers to '*the name given to the process of drawing vertical lines through the music.'*[209] Thus the traditional score format consists of the overlaying and vertical alignment of parts meant to be heard simultaneously. It is intended to be read linearly over time, from

[206] Hanoch-Roe, G., *Musical Space and Architectural Time: Open Scoring Versus Linear Processes*, IRASM 34, 2003, Vol. 2, p.159
[207] Ibid., p.157
[208] Ibid.
[209] Martin, E., '*Architecture as a Translation Music', Pamphlet Architecture 16*, Princeton Architectural Press, Canada, 1994, p.60

left to right. Traditionally, individual instrumental parts are separated onto different staves, often involving the use of a number of clefs according to the range of the instrument (as shown in Figure 5.2a). However, in order to gain an overall representation of the organization of pitch over time, they can be mapped onto a continuous vertical axis, forming a graph of pitch versus time (on the horizontal axis). This graphical format of representing the score has become known as the 'piano-roll' (as shown in Figure 5.2b).

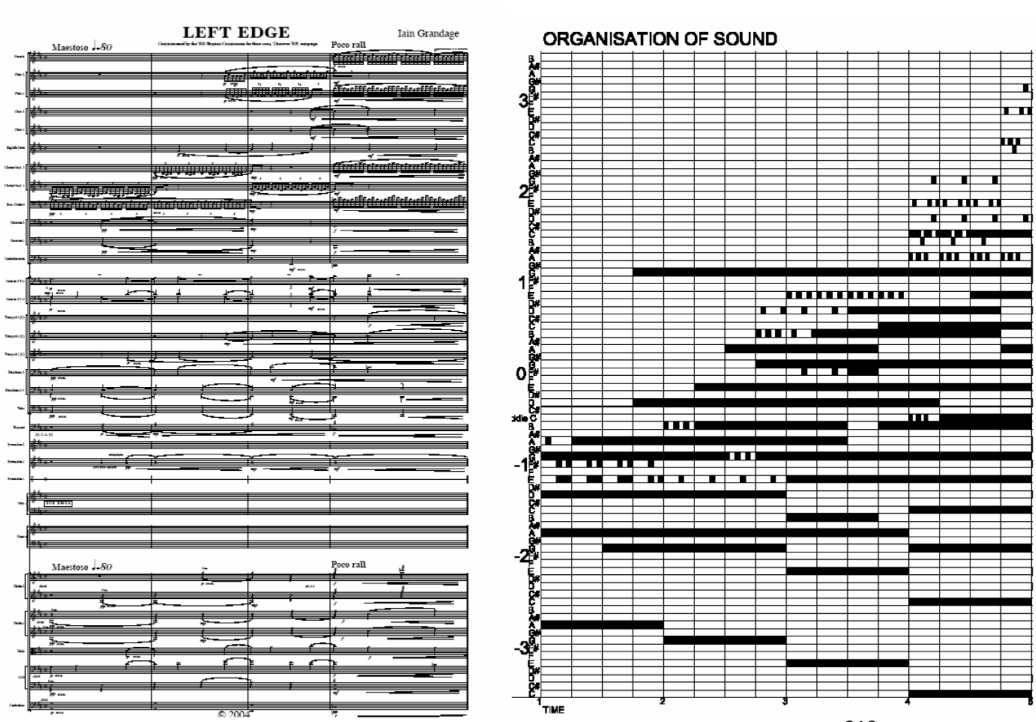


Figure 5.2: Two types of musical representation: a) Traditional score[210]; b) Piano roll[211]

The score is commonly associated with the graphical representation of music. On a more general level, this term also applies to *'symbolizations of processes, which extend over time'*.[212] Thus it is a useful technique of representation in all the temporal arts, including dance and architecture, with the advantage of being able to visually 'freeze time'. This allows it to be read instantaneously and in its totality.

Thus with its need to compose dynamic urban flows in 'frozen' time, the static urban masterplan can be seen as a type of 'score'. In the following section we explore how the score can be used to compose urban motion.

5.2.2 'Scoring' urban design

Hanoch-Roe recognised the potential of the score to inform urban motion through the composition of urban structure and was to propose its use in the 'linear musical process' of the conventional score as the basis for a 'fluid architectural and urban design'.[213]

[210] Ian Grandage, *Left Edge*, 2004
[211] Adhitya, Piano roll representation of *Left Edge*, Ian Grandage, 2006
[212] Halperin 1969, p.1
[213] Hanoch Roe, 2003, p.157

In order to demonstrate how this can be done, we present two urban projects, which are primarily based on the musical score.

Bloch City

One such project is the 1983 Bloch City project by Architect Peter Cook. Here, the conventional music notation is directly translated into urban form, with the musical elements of the stave, bar lines and notes, evolving into the urban elements of roads, bridges and towers, respectively. The result is a literal 'three-dimensionalisation' of the score, as seen in Figure 5.3, in which notes are extruded as towers along roads of musical staves.

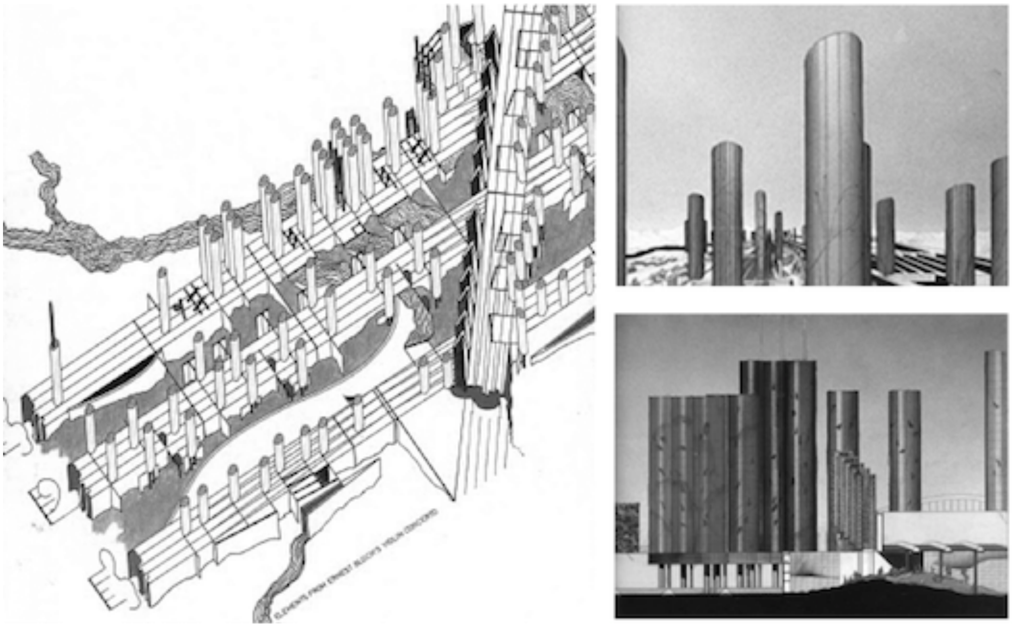


Figure 5.3: Peter Cook, Bloch City, 1983: 'three-dimensionalisation of the musical score'[214]

Left Edge

Another urban project directly translating a musical score is Left Edge[215], an urban waterfront design for Perth, Western Australia. This project is of particular interest due to the music being composed specifically for the site, with the intention to sonically convey its three characteristics – urban, landscape, and water. Here the score was first mapped as a piano-roll (Figure 5.4) before being thematically applied to the site in order to structure the urban, landscape and water experiences along major axes of movement (Figure 5.5). It was scaled according to the principle mode of transportation, as well as catering for multiple points of view, e.g. as experienced from the car as well as the pedestrian. The different urban designs based on each musical theme - urban, landscape and water - are represented in Figure 5.6. The music can be listened to here:
https://www.dropbox.com/s/xohovaqk56pmbiy/Left%20Edge.m4a

[214] Peter Cook, Bloch City, 1983

[215] Adhitya, S., *Perth Foreshore Urban Design project*, based on Left Edge (2006) music by I.Grandage, The University of Western Australia, 2006

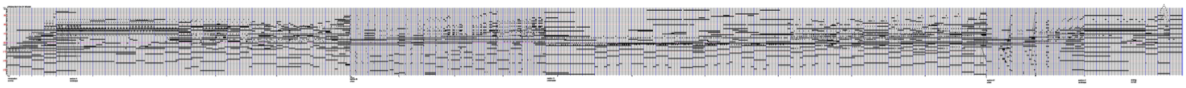


Figure 5.4: Piano-roll of I.Grandage's Left Edge (2004)[216]

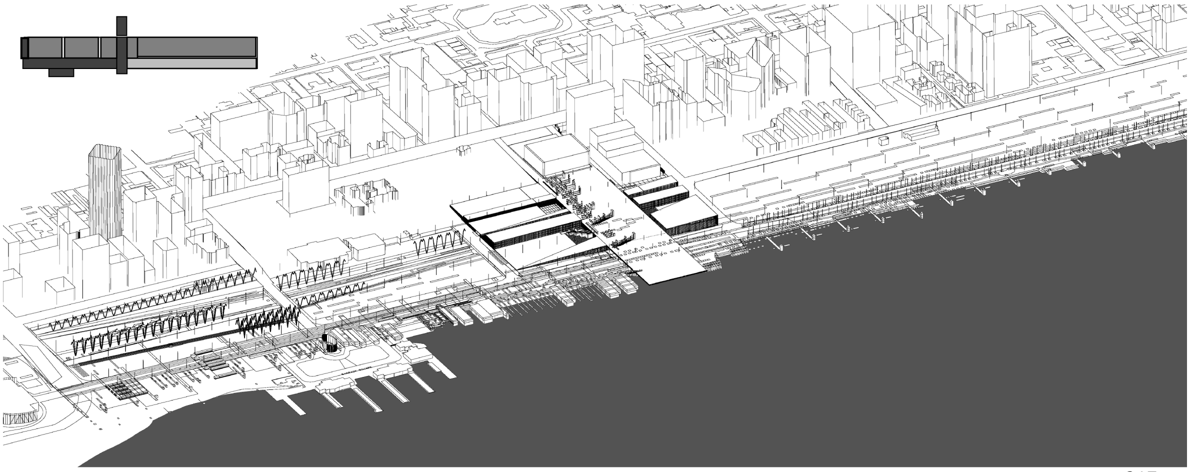


Figure 5.5: Overall plan of Perth Foreshore urban design project, based on Left Edge [217]

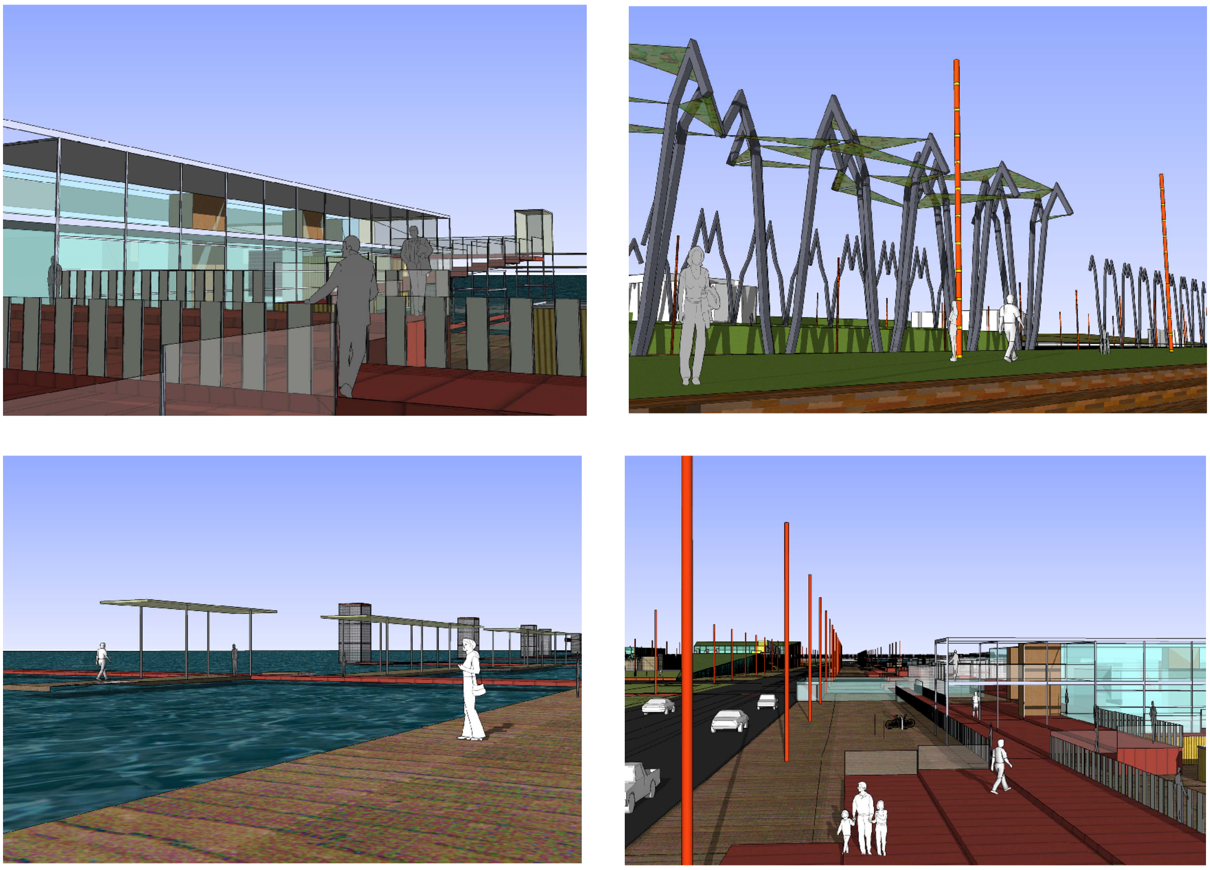


Figure 5.6: Urban designs based on each musical theme
a) Urban b) Landscape c) Water d) Overall [218]

[216] Adhitya, S., pianoroll of Grandage, I., *Left Edge*, 2006
[217] Adhitya, S., *Perth Foreshore Urban Design project* (based on *Left Edge,* music by I.Grandage), B.Arch Honours project, The University of Western Australia, 2006

5.2.3 The Open Graphic Score

The development of the graphic score since the mid-20th century, by composers such as Cage, Boulez, Ligeti and Stockhausen, has seen contemporary musical notation become '*an aesthetically moving object in its own right.*'[219] Rather than adhering to the musical notation conventions seen earlier in the traditional score, nor the linear graph-like structure of the piano roll, the graphic score is presented as an image and utilizes any number of graphic techniques chosen by the composer. As described by Cage, '*there is no point-to-point communication*', [220] leading to its description as an '*open*' structure. As opposed to the prescribed singular linearity of the traditional score, it can be read and interpreted from a multitude of perspectives.

For this reason, the open graphic score has often been referred to as an urban plan, an analogy utilized by Boulez in describing the structure of his Third Piano Sonata:

'*I have often compared this work with the plan of a city. One does not change its design, one perceives exactly what it is, and there are different ways of going through it. One can chose one's own way through it, but there are certain traffic regulations.*'[221]

However, Boulez's open score still utilized traditional musical notation. Greek composer Anestis Logothetis, however, was to criticise the linear nature of time in traditional notation:

'Traditional notation is divided into systems and is read for left to right, like that of books. But since sound is not bound to the same concept as words, we could think about using pictorial notation to present musical events. (...) Because the music "time" doesn't go by from left to right'.[222]

In an attempt to liberate time from its self-imposed 'linearity', composers began to develop their own graphic notation techniques, leading to the development of the graphic score in the second half of the 20th century. Logethesis used such non-linear scores to compose stories over time, and many can thus be seen as plans of movement. For example, his score for the ballet Odysee (1963) can be seen as a choreographic plan for the trajectory of its dancers, as delineated on the right of Figure 5.7.

[218] ibid.
[219] Hanoch-Roe, 2003, p.157
[220] Cage, J., 'Form is Language', in Kostelanetz, R.,(ed.), *John Cage*, Praeger Publishers, New York, 1970, p.135
[221] Boulez, P., *Third Piano Sonata*, 1958
[222] Logothetis, A.,*"Über die Darstellung des Klanges im Schriftbild", Impluse: für Spielmusikgruppen*, Universal Edition, Wien, 1973, p. 3-9

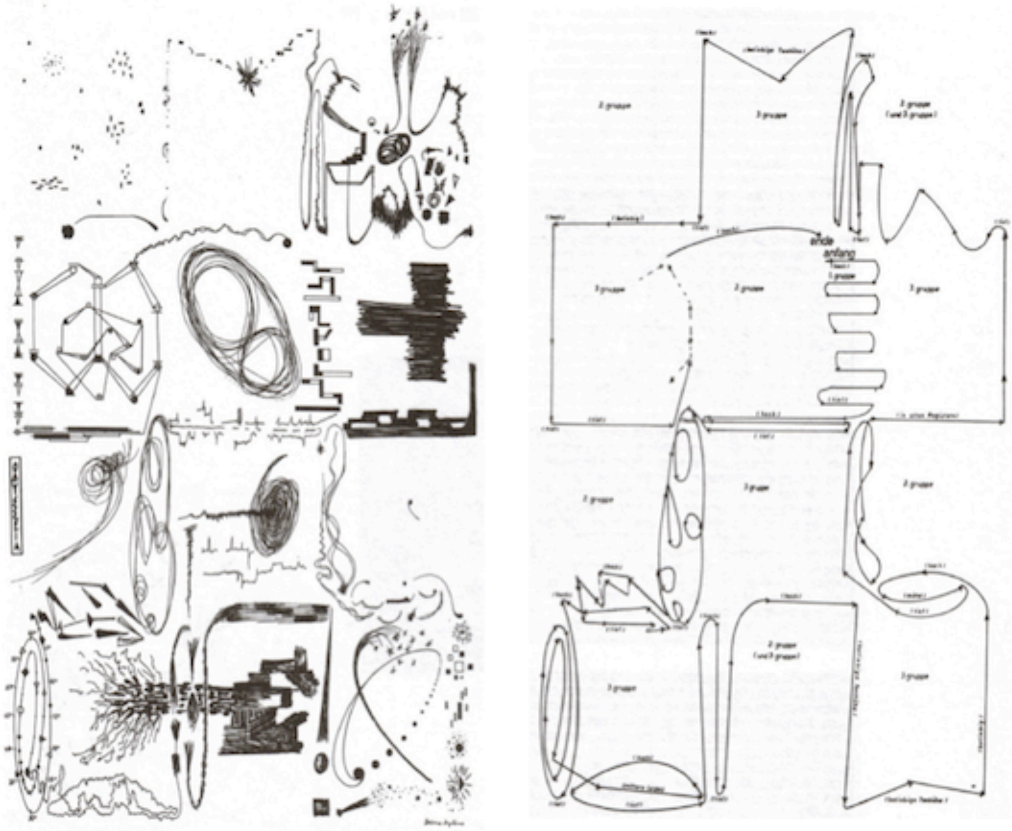


Figure 5.7: Logothetis, graphic score of *Odysee (1963)* with trajectory of dancers (on right) [223]

John Cage was to similarly continue this reference to the composition of urban motion by comparing the performer to a '*traveller trying to catch trains and departures, which have not been announced but are in the process of being announced'*.[224] Just like an architect, the composer provides the structure for a certain number of possibilities, but in the end the performer chooses his or her path. The open graphic score can thus be seen as a suitable representational technique for both composers and urban designers alike for the structuring of aleatory flows.

A graphical approach to music notation has also grown out of the need to represent music which is not based on traditional score representation, e.g. electroacoustic, ethnic, and jazz. Such computer-aided composition techniques as the Acousmographe and the UPIC will be explored in Chapter 6 in our aim to represent the masterplan as a score.

5.2.4 Score as synchronizer

Furthermore, the graphic score plays an important role in the synchronization of simultaneous events, i.e. the generation of polyphony. As seen earlier, this was represented in the traditional musical score by vertically superimposing the individual staves of each part and aligning them with bar lines. Cage was to literally materialize this process of layering in

[223] Georgakis, A., 2008
[224] Hanoch-Roe, 2003, p.156

his 1958 graphic score Fontana Mix (Figure 5.8), by using 10 sheets of paper and 10 transparencies, consisting of lines and points respectively. With a further two transparencies containing a grid and a line, the superimposition of these layers, in various combinations, created a multitude of structures and thus possible scores. The interaction between these forms was assigned to the musical attributes of volume, tone, colour and pitch.

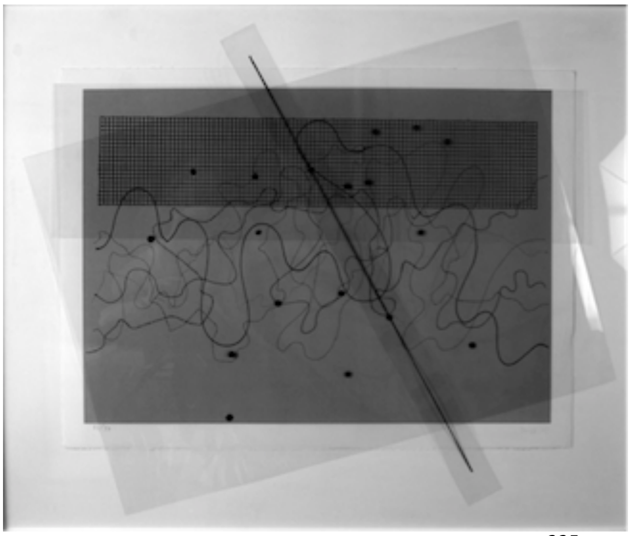


Figure 5.8: John Cage: Fontana Mix[225]

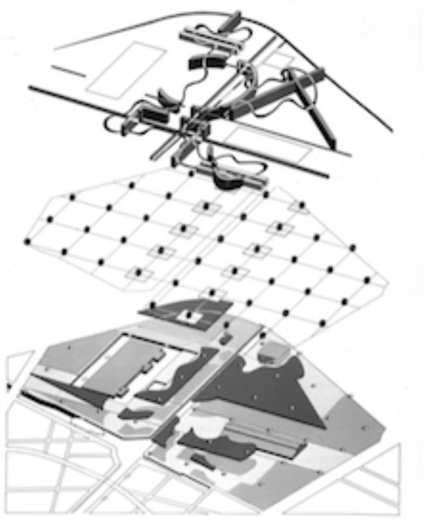


Figure 5.9: Bernard Tschumi: La Villette[226]

This process of layering different formal typologies is equally relevant to urban design, which itself is a composition of geometric forms which work to structure a certain dynamic. Thus Martin calls for a compositional strategy in architecture, which is not singular and object-based, but instead involves the 'analysis, layering and synthesis into a unified entity'[227]. One such project utilizing the concept of layering as the primary design generator is Tschumi's Parc de la Villette in Paris. From three superimposed layers of point, line and plane objects each having their separate urban roles, an urban composition is generated (Figure 5.9). The synthesizing ability of the graphic score can help in the synchronisation of multiple urban systems.

Conclusions: Masterplan as graphic score

Thus while traditional musical score has been explored for its potential to inform urban design, the 'plan-like' open structure of the graphic score can perhaps be seen as even more adapted to the multi-dimensional structure of the city. In addition to its ability to support multiple temporal paths and spatial perspectives, the process of layering offers the ability to graphically synthesize multiple, simultaneous events. In the next section, we develop the idea of the masterplan as a graphic score, exploring how it can be 'played' in order to reveal the urban rhythms of interest.

[225] John Cage, *Fontana Mix,* 1959 (John Cage Trust)
[226] Bernard Tschumi, *La Villette*, 1983
[227] Martin, 1994, p.60

5.3 Urban Masterplan as Graphic Score

'… listening to a house, a street, a town as one listens to a symphony, an opera…'[228]

In this section, we explore how we can 'capture' the rhythms embedded in the urban masterplan. We first present how different rhythms can be 'read' at various scales, before exploring how the urban masterplan can be 'played' in order to articulate these rhythms.

5.3.1 Representing urban rhythm

The urban masterplan is used to represent the physical structure of the city at a number of different scales, such as regional, metropolitan, or neighbourhood, as shown in Figure 5.10. This determines the level of structural detail that can be observed.

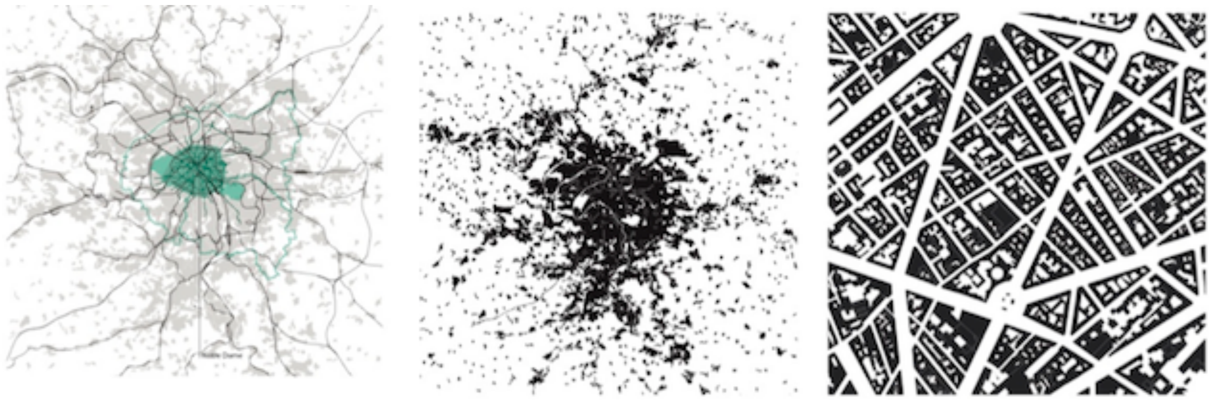


Figure 5.10: Different urban scales of Paris: i. regional; ii. metropolitan; iii. neighbourhood [229]

At each scale, the urban system can be seen in terms of its urban form and the urban flows it structures: people; their activities, and their transport movements. Thus a hierarchy of rhythms can be seen to exist, with these rhythms 'nested' within each other at each level. For example, in observing the urban fabric at city scale, we observe the rhythm of building blocks, whereas at the neighbourhood scale we can appreciate the rhythm of each building. The rhythms as generated by the physical structure of the city can be summarised as in Table 5.1 below.

Table 5.1: Urban rhythms as structured by urban form[230]

Urban Structure	**Urban rhythms**
Transport infrastructure	Transport flows
Built Form	Activity distribution
Urban Design	Pedestrian experience

[228] Lefebvre, 2001
[229] image source : London School of Economics, Urban Age Programme, in Rogers et.al., *Le Grand Pari De L'agglomération Parisienne - Consultation Internationale pour l'avenir du Paris Métropolitain*, Dec. 2008, p.8
[230] Adhitya, 2013

5.3.2 'Reading' urban rhythm

As previously explained, a rhythm is the *'interaction between a place, a time and an expenditure of energy'*[231]. Thus revealing these rhythms will involve the articulation of the interaction of each urban flow with its urban structuring element of interest. The urban flow, as the dynamic element of the urban system, can be seen as the 'exciter' of the interaction. Thus, the production of rhythm can thus be viewed as primarily 'path-based'. The urban form, as the static element, thus becomes the instrument to be played, as seen in Figure 5.11.

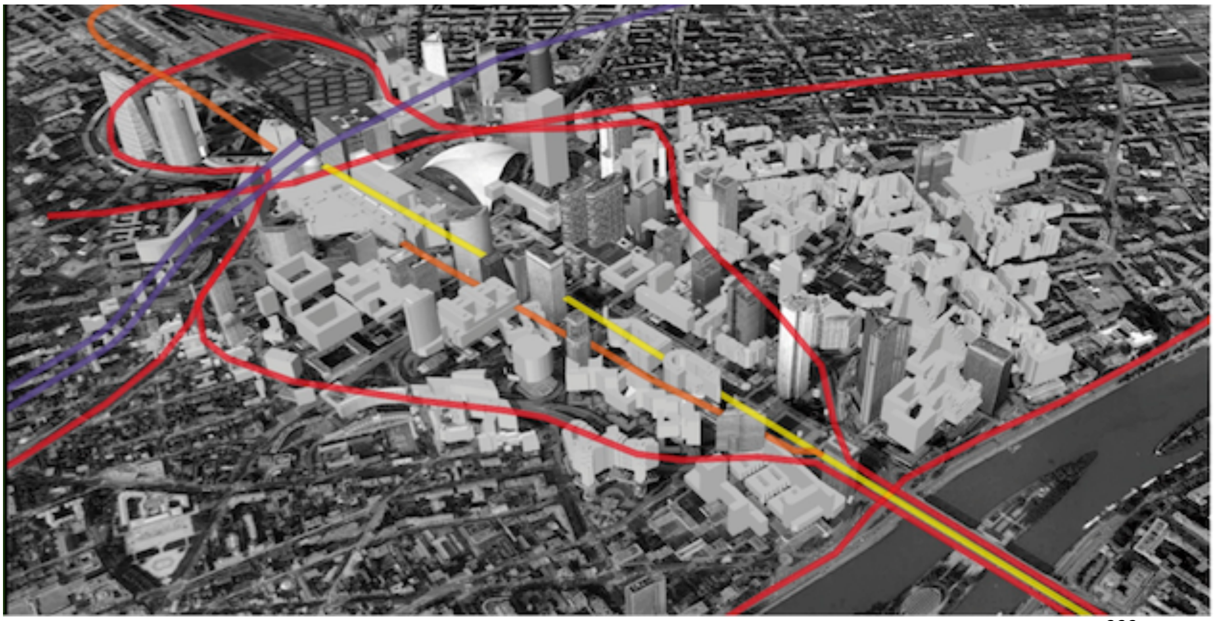


Figure 5.11: Playing the city – the interaction of paths with built form over time [232]

The reading of an urban rhythm also depends on the point of view from which we perceive it: internally, as seen from the point of view of the moving object itself; and externally, as seen from the point of view of an observer. The first allows us to either a) experience it subjectively, or b) analyse it 'objectively'. Parallels can be drawn with flow theory, recently applied to urban dynamics by Batty and Cheshire,[233] in which two frames of reference are identified:

a). Eulerian: in which flows are viewed in a particular place, over a period of time. This allows us to observe and record the rhythms in a chosen place. We will call the rhythms generated by these flows '*Rhythms of Place'*, as shown in Figure 5.12a.

b). Lagrangian: in which flows are experienced from the point of view of an abstract body travelling along a certain path at a certain speed. This allows us to observe the rhythms along the trajectory of the object itself, with respect to changing location. We will call the rhythms experienced by this flow, '*Rhythms of Path'*, as shown in Figure 5.12b.

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[231] Lefebvre, 2004, p.15

[232] Rogers et.al., *Le Grand Pari De L'agglomération Parisienne - Consultation Internationale pour l'avenir du Paris Métropolitain*, February 2009, p.138

[233] Batty, M., Cheshire, J., Environment and Planning B: Planning and Design 2011, volume 38, p.195

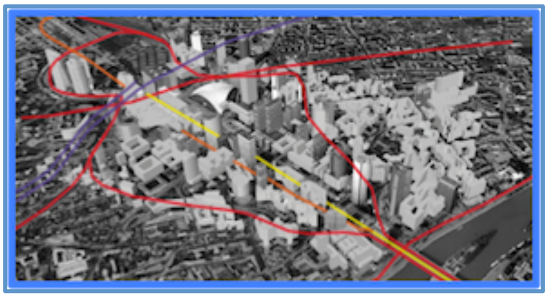

Figure 5.12:[234] *a) Rhythms of Place vs. b) Rhythms of Path*

5.3.3 Articulating urban rhythm

Once identified, the urban design rhythms must be articulated. The rhythms experienced along a path of interest can be revealed by articulating its interaction with the elements of interest along this path. By articulating the rhythms of a system of paths in a chosen place over time, we can also capture the rhythms of that place.

In terms of a musical score, each path becomes a separate 'time-line', with its own individual tempo. Over time, it produces a sequence of rhythmic events which can be considered like a musical part. In combination with other paths, a polyphony of parts is generated which can be viewed as a musical score.

Conclusions: 'Playing' the urban masterplan

In this chapter, we explained how the urban masterplan can be read rhythmically by articulating the interaction of paths with its graphic urban structure. In order to 'hear' these urban rhythms, we proposed their *sonification* and the formation of audio-visual objects.

In order to 'play' the masterplan as a musical score, and thus reveal its rhythms, we propose its representation using the temporal medium of sound. In particular we propose the audio communication technique of '*sonification*' – the representation of data through auditory means – allowing the desired attributes of the masterplan to be literally 'listened to'. In the next chapter, we explain the technique of sonification, towards the development of a 'sonified' urban masterplan.

[234] based on image by Rogers et.al., 2009, p.138

6 An Urban Sonification Strategy

In this chapter, we examine the technique of sonification in further detail, with the objective to develop an audio-visual tool for the sonification of the masterplan. We are essentially concerned with the translation of images into sound, allowing existing plans to be played like the previously described graphic scores. However, as our aim is not only to analyse but also to design new plans, we also require a tool allowing us to compose graphically.

6.1 Introducing Sonification

'There are clear parallels between the composer's role in AD (auditory display) and the graphic artist's role in data visualization.'

Gregory Kramer[235]

Sonification can be considered as the auditory equivalent of graphic representation in the visual domain.[236] Introduced in 1994 by Kramer, it is known in general as the representation of data - information, events and processes - through auditory means. [237] Being an emerging field of research, its definition has been in constant evolution over the past 20 years.

Carla Scaletti (1994) proposed the following working definition of sonification:

'a mapping of numerically represented relations in some domain under study to relations in an acoustic domain for the purpose of interpreting, understanding, or communicating relations in the domain under study'. [238]

The National Science Foundation White Paper (1999) defined sonification as:

'the use of nonspeech audio to convey information. More specifically, sonification is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation'.[239]

In an attempt to differentiate sonification from other similar practices involving the systematic sound synthesis from data e.g. in the sonic realm of composition or sound art,

[235] Kramer, G. (ed.), *Auditory Display - Sonification, Audification, and Auditory Interfaces*, Addison Wesley, 1994, pp. 52–53

[236] de Gotzen et.al, in Polotti, P., Rocchesso, D., (Eds.), *Sound To Sense, Sense To Sound - A State Of The Art in Sound and Music Computing,* Logos Verlag, Berlin, Germany, 2008, p.416

[237] Kramer, 1994, p.185-221

[238] Ibid.

[239] Kramer et al., *Sonification report: Status of the field and research agenda. Technical report*, ICAD/NSF, 1999., p.149

Barrass and Vickers proposed the following design-centric definition, which focuses on its functional intention, rather than its systematic process[240]:

'Sonification is a rendering of data to sound with the purpose of allowing insight into the data and knowledge generation about the system from which the data is gathered. We propose that the defining feature of sonification is a pragmatic information aesthetic that combines the functionality of information design with the aesthetic sensibilities of the sonic arts.' [241]

This definition is inclusive of both functionality and aesthetics, allowing the same data to be sonified in different ways, according to their intended function. Thus it also avoids issues of interpretation and objective communication. This is similar to the sound design definition outlined by Ircam's Sound Design and Perception team[242], which draws on the design duality of form and function. The form of the sound refers to its aesthetic quality, whether material or abstract, while its function refers to the information or interaction it intends to communicate to the audience or user. In our sound design strategy, we propose this dual approach of 'form and function'.

6.1.1 Why sonification?

The advantages of an auditory representation technique include the temporal representation of data and the ability to represent multidimensional data sets. It benefits from the 'polyphonic' ability of the ear to perceive and distinguish between multiple simultaneous auditory streams.[243] It also capitalizes on the efficiency of the ear to detect temporal patterns (e.g. periodicity) or short events that often escape the eye in noisy visual displays, and thus is becoming increasingly used for analytical purposes.[244]

Studies have shown that *'... audition plays a greater role than vision in the processing of temporal information.'*[245] This includes the perception of rhythm and temporal discrimination.[246] Thus, sonification is suitable for temporal data analysis,[247] including the detection of temporal patterns and anomalies not discernible by sight.[248] It can also help in the observation of data trends and to determine the overall morphology of a data set.

[240] Ibid., p.152
[241] Ibid.
[242] Définition et processus du design sonore - Le design sonore: faire entendre une intention http://pds.ircam.fr/906.html, [Accessed May 2013]
[243] Gotzen, et al., 2008, p.418
[244] Dayé, C., de Campo, "Sounds sequential: sonification in the social sciences", in *Interdisciplinary Science Reviews*, 2006, vol.31, no.4, p.354
[245] Kubovy, M., Schutz, M., *Audio-Visual Objects,* Review of Philosophy and Psychology, March 2010, vol.1, issue 1, pp.41-61
[246] Neuhoff, in Hermann et al. (eds.), *The Sonification Handbook,* 2011, p.73
[247] Ibid.
[248] Ferguson, Martens, Cabrera, in Hermann et al. (eds.), *The Sonification Handbook,* 2011, p.178

6.1.2 Applications of Sonification

The applications of sonification are varied, and has so far been categorised as follows:

1. alarms, alerts, and warnings;
2. status, process, and monitoring messages;
3. data exploration; and
4. art, entertainment, sports, and exercise.[249]

These different functions call for different sonification techniques, which will be explained in the following section. Our interest in urban sonification is primarily concerned with the exploration of urban data. The application of sonification to the urban realm has so far ranged from the analysis of various urban data sets[250], to the interactive sonification of geo-referenced data for navigation by the visually-impaired or for educational purposes[251]. However, the use of sonification as an urban planning and design tool can be explored further.

Last but not least, the interesting audio results achieved so far by data sonification has led to a recent interest in its potential for music composition. Thus, depending on the defined mapping process, data sonification can be at once both functional and musical. [252]

6.1.3 Sonification Process

The sonification process involves the systematic transformation of a given dataset into sound, through a defined mapping process. Being a form of perceptualization, sonification like visualisation, involves some form of mapping.[253] The process is indicated in Figure 6.1.

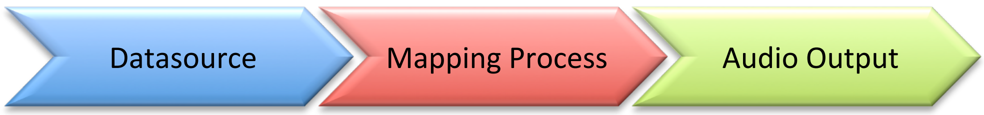

Figure 6.1: Sonification process

Hermann was to specify four conditions for the use of sonification as a scientific method:

- The sound reflects objective properties or relations in the input data
- The transformation is systematic, with precise definitions given
- The sonification is reproducible, under the same conditions
- The system can intentionally be used with different data and repeated with the same [254]

Thus the sonification mapping process must be systematic, objective and reproducible. [255]

[249] Walker, Nees, 2011, p.12
[250] C. Dayé, de Campo, 2006, p.354
[251] Heuten et.al., 2006
[252] Map of Sound, http://sonification.de/publications/media/Hermann2008-TAD.pdf
[253] Ibid., p.153-4
[254] Hermann, 2008

6.2 Approaches to Sonification

'Building a sonification involves mapping the data source(s) onto representational acoustic variables.'

Walker and Nees[256]

Sonification involves the representation of data into sound through some sort of mapping process. There are a number of approaches to this mapping process, depending on the required function. These include: audification; icons-earcons; parameter-mapping; and model-based sonification. In our search for an appropriate sonification model for our sonified urban masterplan, we outline each of them briefly below. They will be explained in terms of their acoustic dimensions in Chapter 8. The aim is to develop an effective urban sound design strategy for communicating urban data in sound.

6.2.1 Audification

Audification involves the direct translation of a periodic data waveform into the audible range.[257] Processing is limited to direct amplification, or filtering.[258] Thus its range of applications is limited, with a notable example being the seismogram for the sonic representation of seismic data.

6.2.2 Auditory Signs

A sign can be defined as an element of communication which represents something other than itself.[259] Auditory signs thus involve the communication of information through sound. Below we discuss the different types of techniques for auditory signs which have so far been used in auditory display design. They vary according to the kind of communication required and thus appeal to our perception in different ways.

Auditory Icons

Auditory icons were first introduced by Gaver in the 1980's, in response to the new desktop computer interface and the need to rethink the human-computer interaction paradigm:

'Auditory icons mimic everyday non-speech sounds that we might be familiar with from our everyday experience of the real world, hence the meaning of the sounds seldom has to be learnt as they metaphorically draw upon our previous experiences.'[260]

[255] Walker, Nees, in Hermann et al. (eds.), *The Sonification Handbook,* 2011, p.9
[256] Kramer, 1994 in Walker, Nees, 2011, p.22
[257] Kramer, 1994, Dombois, Eckel, in *The Sonification Handbook,* 2011, p.301
[258] de Gotzen et.al, 2008, p.411
[259] Ute Jekosch, Assigning Meaning to Sounds – Semiotics in the Context of Product-Sound Design. In Communication Acoustics, J.Blauert, Springer Berlin Heidelberg, 2005, p.193
[260] Brazil, Fernstrom, in *The Sonification Handbook,* 2011, p.325

They are often considered to be the 'auditory equivalent' of visual icons,[261] based on the same ecological theory of visual perception introduced by Gibson at the time.[262] They rely on metaphor, and for this reason often use everyday, environmental sounds to iconically represent functions, objects or events. Due to their effectiveness, considered relatively intuitive, their popularity has spread from the computer user interface to other forms of human computer interaction, as well as sonic interaction design.

Earcons

Earcons were originally defined by Blattner et al. in 1989 as: "*non-verbal audio messages that are used in computer / user interfaces to provide information to the user about some computer object, operation or interaction*".[263]

These auditory messages usually consist of short, abstract tones which can be structured in different ways to create new signs, much like the composition of a musical grammar.[264] However, unlike auditory icons, Earcons must be learned since no existing relationship is assumed between the sound and the information it represents.

Other types of auditory signs

While the two most-commonly used techniques are Auditory Icons and Earcons, a number of other approaches to auditory signs have also been explored in auditory display design.

Spearcons consist of accelerated speech to create a 'speech-like sound' for the communication of a function.[265] For this reason, they are culturally and semantically dependent and thus not advisable for universal use.

Musicons are short sections of existing music (approximately 0.5 seconds) for use as auditory cues.[266] *Musicons* have performed comparably to speech, in terms of both speed and accuracy of identification. [267] However, like speech, their reliability on context makes them culturally-specific.

'Iconic' Earcons can be developed through the use of more metaphorical mappings between the sound and data. Research by Leplâtre, Brewster, Alty and Rigas has shown that earcons can be designed to promote their implicit learning. With meaning being demonstrative, the need for training has the potential to be reduced.[268]

[261] Brazil, Fernstrom, 2011, p.325
[262] Gibson. *The Ecological Approach to Visual Perception*. Lawrence Erlbaum Associates Inc. Publishers, Hillsdale, NJ, USA, 10th (1986) edition, 1979
[263] de Götzen, 2008, p.404, and McGookin, Brewster, in *The Sonification Handbook*, p.339
[264] McGookin, Brewster, in Hermann et al. (eds.), *The Sonification Handbook,* 2011, p.339
[265] Ibid., p.351
[266] research by McGee-Lennon et al., in Ibid, p.352
[267] Ibid., p.352
[268] Ibid., p.357

Last but not least, *Hybrid Icon-Earcons* have been created by combining Auditory Icons and Earcons. The idea is to overcome the parameterisation problems of Auditory Icons and the training issues of Earcons, although further research is needed to understand their full potential.[269]

6.2.3 Parameter-mapping sonification

Parameter-mapping involves the translation of one set of data parameters into one or more acoustic attributes. As a sound consists of multiple attributes itself, one sound can be used to represent multiple data variables. Furthermore, a number of data dimensions can be represented simultaneously, allowing the sonification of multivariate data.[270] Different mapping dimensions are possible, according to the data space and the available sound synthesis parameters:

1. *'one-to-one' mapping* can be used for mapping to independent parameters, i.e. In the signal domain. [271]

2. *'one-to-many' mapping (divergent mapping*) involves the mapping of one data feature to several synthesis parameters[272]

3. *'many-to-one' mapping* (*convergent mapping*) – due to the perceptual interdependence of sound synthesis parameters e.g. when mapping two or more data features to physical modelling processes.[273]

This flexibility allows the representation of data spaces for the following purposes, and defined by their mode of inquiry: [274]

- *Exploratory PMSon* - for the spatial exploration of data, involving non-sequential inquiry called 'probing'
- *Observational PMSon* - for the observation monitoring of time series or sequential data streams, and thus involving a sequential inquiry mode called 'scanning'
- *Exploratory-observational PMSon* is a hybrid approach which involves the probing of temporal data.

The input data can take on a number of different forms, from numerical datasets to static and moving images. Apart from data analysis to visual aids, there have also been numerous artistic applications of PMson, including '*musification*' works based on: DNA; solar activity, tides, and meteorological records; geographical coordinates; geometric relationships and mathematical processes; architectural proportions; as well as statistical and stochastic

[269] Ibid., p.352
[270] Hermann, T., "Taxonomy and definitions for sonification and auditory display", *Proceedings of ICAD 2008*, IRCAM, France
[271] Hermann, 2011, p.370
[272] Ibid.
[273] Ibid., p.371
[274] Grond, Berger, in *The Sonification Handbook*, 2011, p.381

processes e.g. Xenakis, Metastasis (1965). [275] In our sonification of the graphic masterplan, we are interested in mapping graphical parameters, such as color and location.

6.2.4 Model-based sonification

Last but not least is the technique of *Model-based sonification*, which involves the development of a sonification model or *instrument* (a sound-capable object) toward an interactive exploration of a data space.[276] Like a musical instrument, the model must be 'played' by a user to produce an acoustic response. While possibly incorporating parameter-mapping, according to Hermann '*it is no longer a mere mapping of data to sound'* as the structural information is encoded into the sound signal.[277] Rather than the data 'playing' the instrument, the data set itself 'becomes' the instrument and the playing is left to the user.[278]

Model-based sonification is suitable for the sonification of a-temporal data. It is also useful in promoting user-interaction, as the inquiry process is based on the user excitation of the model. It draws on our *inverse mapping skills* from sound to interaction in order to understand the model and in turn the underlying data.[279]

Conclusions: An 'Urban' Sonification Process

In the development of a sonification strategy for any application, the most appropriate approach is the meeting of function and technique. In our aim to sonify the urban masterplan, we are essentially interested in the translation of image into sound. Thus we will first use a parameter-mapping approach to translate graphic parameters into audio attributes, as shown in Figure 6.2. This will allow us to 'build-up' the masterplan as a sonified graphic score, allowing it to be played in a similar way to an instrument in model-based sonification.

Figure 6.2: Urban sonification process

In the next section we will explore existing image-based audio tools which may be useful in the translation of image into sound.

[275] Ibid., p.390
[276] Hermann, *The Sonification Handbook*, 2011, p.399
[277] Barrass, Vickers, 2011, p.153
[278] Hermann, 2011, p.424
[279] Ibid., p.402

6.3 Towards an Urban Sonification tool

In the development of an urban sonification tool, we are primarily concerned with the translation of image into sound, i.e. image sonification. At the same time, we are interested in the graphical composition of urban objects for future planning and design, i.e. graphical composition. In order to support the multiple spatio-temporal flows of the urban system, we require a tool in which we can support the definition of multiple spatio-temporal time paths. Furthermore, for both urban analysis and design, the tool must support both the importation of multiple raster images and the creation of vector objects. Such a tool thus combines the functions of both image sonification and graphical composition. Below is a summary of the requirements of our proposed tool:

- Multiple time axes
- Multiple spatio-temporal paths
- Multiple layers
- Image sonification and graphical composition
- Raster importation and vector creation

Here we explore existing image sonification and graphical computer-aided composition tools in terms of these criteria.

6.3.1 Image sonification tools

With the point of departure being the graphic masterplan, amongst the growing field of sonification toolkits[280], we focus only on those orientated towards the transformation of image data.

SonART[281] is a sonification tool for the integration of image and sound processing. Based on the notion of the soxel as a sonic equivalent to the pixel, bitmap images can be mapped to pitch, time, position and timbre. It supports multiple layers of image canvases which can be read by raster-scanning or real-time probing. Intended for image data exploration and analysis, it also allows real-time, audio-visual, networked, multimedia performances via its OSC output for synthesis or audio signal processing. While it allows the control of the opacity and RGB color composition of each canvas, it does not allow the creation and manipulation of vector objects.

COMPath[282] allows the path-based sonification of geometric, georeferenced data. The user draws a path over an online map interface, transforming the information along this route into sound events. The result depends on the existing data and thus while 'compositional'

[280] *Personify, Listen, MUSE,* and *Interactive Sonification Toolkit*
[281] Lee, Z., Berger, J. & Yeo, W., *Mapping sound to image in interactive multimedia art,* Technical report, CCRMA, Stanford University, 2004, https://ccrma.stanford.edu/~woony/software/sonart/ [Accessed April 2011]
[282] Park, S., Kim, S., Lee, S., and Yeo, W., *Composition With Path: Musical Sonification Of Geo-Referenced Data With Online Map Interface,* Audio & Interactive Media (AIM) Lab, GSCT, KAIST Daejeon, Republic of Korea, 2010

decisions can be made, new events cannot be generated. Furthermore, although the direction of time is not restricted, it is not possible to simultaneously sonify multiple paths.

Audiograph and ***Smartsight***[283] are two comparatively simplistic attempts to translate graphical material into sound. These use left-to-right image scanning, mapping distance to pitch, and are thus most useful for the representation of graphs. While limited information is available on these tools, they have been described to have been used for the communication of graphs or basic shapes to the blind.

6.3.2 Graphical composition tools

The growing interest in visual music has also contributed to the development of tools which facilitate a more graphical approach to composition and sound synthesis. Automating this process of 'drawing' music has led to various computer-aided composition tools.

The UPIC

The earliest attempt to create an automated graphic composition tool is the UPIC, the *Unité Polyagogique Informatique*[284] developed by Iannis Xenakis at the *Centre d'Etudes de Mathématique et Automatique Musicales* (CEMAMu), Paris, in 1977. A civil engineer and composer, Xenakis (1922-2001) developed his UPIC system using a graphical tablet and computer with vector display for graphical audio synthesis at both the micro and macro scale.

The UPIC (Figure 6.3) supports the drawing of sound waves, volume envelopes, and timbres, which are then rendered by the computer. The user can then use these waveforms to compose their overall structure. The X-axis represents time and the Y-axis represents pitch, and thus lecture is limited in the horizontal axis. Here a musical composition is represented as a set of drawn marks on a score sheet, where the horizontal position and span of the mark represent the time at which they occur and the vertical axis represents the evolution of their pitch. Xenakis' composition *Mycenae Alpha* (Figure 6.4) was one of the first pieces created with the UPIC.

Figure 6.3: The UPIC system [285]

Figure 6.4: Mycènes Alpha (1978)[286]

[283] Edwards, in *The Sonification Handbook*, 2011, p.448-9
[284] http://en.wikipedia.org/wiki/UPIC [Accessed August 2012]
[285] http://membres.multimania.fr/musicand/INSTRUMENT/DIGITAL/UPIC/UPIC.htm [Accessed August 2012]

The UPIC has since inspired commercial systems, such as *Iannix* and *HighC,* which as we will see operate in very different ways.

The ***Acousmographe***[287], first developed in 1991 by the Groupe de Recherches Musicales (GRM) in Paris, is a software for the graphic representation of acoustic signals and music. It facilitates the identification, annotation and detailed description of all recorded music. This is particularly useful in the visual representation of music of the oral tradition, for use in musicological analysis or teaching, as well as the study of phonetics and sound perception. Its many graphical tools are also useful for the generation of electroacoustic music scores, as shown in Figure 6.5. It allows the development of a graphic-sound legend, however time is constrained to the horizontal time-axis.

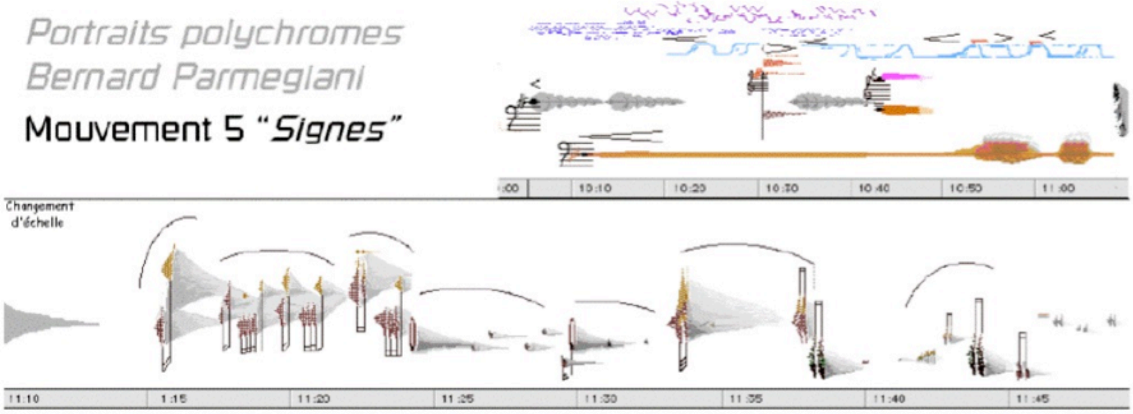

Figure 6.5: Acousmographe transcription of Parmegiani 'L'Oeil Écoute', P. Mion, 2004 [288]

HighC[289](1996) is a commercial software for graphical audio synthesis based on Iannis Xenakis' UPIC system. One can draw notes, envelopes and wave shapes, rhythms or patterns, and basically 'sketch' music. However, time is still restricted to the horizontal axis, while pitch on the vertical, as in the style of a piano-roll. (Figure 6.6)

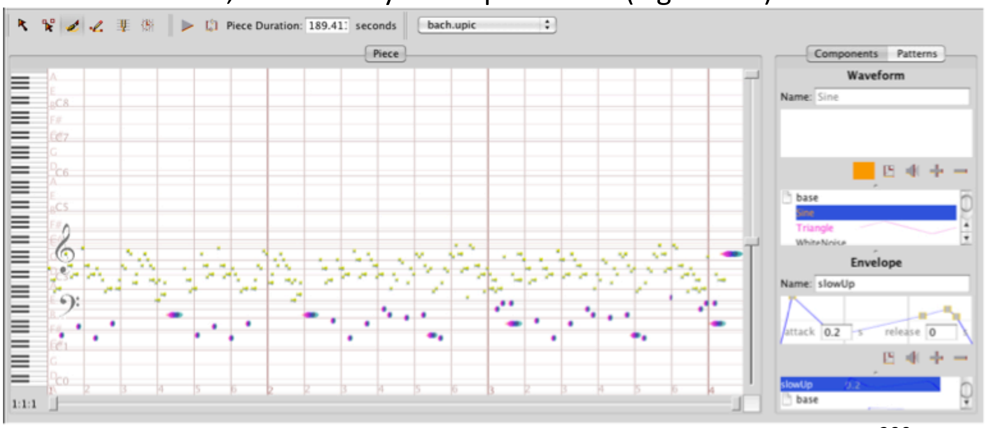

Figure 6.6: HighC user interface with piano-roll representation[290]

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[286] Xenakis, *Mycènes Alpha*, 1978

[287] http://www.inagrm.com/sites/default/files/mini-sites/acousmographies/co/Acousmographies.html [Accessed January 2013]

[288] Geslin, Y., Lefevre, A., 'Sound and musical representation: the *Acousmographe* software', in *Proceedings of ICMC,* 2004, p.3

[289] http://highc.org/ [Accessed January 2012]

[290] Ibid.

Metasynth[291] is a comprehensive toolkit for the 'painting' of sound and its graphical manipulation, including the use of filters, spectral analysis, effects, a sequence editor, and a timeline editor for large-scale structural organization. However, despite these advanced editing tools, its compositional structure is still limited to a single horizontal time line.
Audiopaint[292] is essentially an additive synthesizer which processes raster images as a frequency / time grid. Pixel color and position is converted to amplitude, frequency (vertical position), and time offset (horizontal position). Thus it does not allow the directional reading of the image nor image editing tools.

Iannix[293] is a graphical open source sequencer allowing computer-aided composition in multiple spatial and temporal dimensions. However it is vector based and does not allow the sonification of raster images.

Last but not least, visual programming environments for computer-aided composition, such as ***PWGL***[294] or ***OpenMusic***[295], are oriented towards the description of object-based graphical scores. PWGL's internal music notation editor of its Expressive Notation Package[296] (ENP) has a device called 'canvas-expression' which allows basic graphical composition from a predefined selection of graphical objects. However, it does not allow the pixel-by-pixel exploration of a score as an image.

6.3.3 Limitations of existing tools

When translating information between the visual and auditory domains, the problem of representing and organizing time is imperative. As we can see, the majority of the aforementioned applications are limited to a single horizontal time axis, restricting the temporal structure of a sonification to one dimension. Most of the toolkits also operate on a single image layer, and thus do not adequately support the polyphonic nature of the urban system. In addition, current sonification tools do not support the creation of graphical information within the tool itself, which is necessary for design purposes.

In the following chapter, we will discuss the development and implementation of an image sonification/ and graphical composition tool which fulfils our proposed requirements. We term this tool the '*Sonified Urban Masterplan*' (SUM), and while it is initially intended for use by urban professionals, we hope that it will also be accessible to the general public.

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291 www.uisoftware.com/MetaSynth/index.php [Accessed January 2012]
292 http://www.nicolasfournel.com/audiopaint.htm [Accessed January 2012]
293 http://www.iannix.org/en/index.php [Accessed January 2012]
294 Laurson M., Kuuskankare M., Norilo V., *An Overview of PWGL, a Visual Programming Environment for Music*, In: Computer Music Journal, 2009, vol. 33, no.1, pp.19–31
295 Openmusic, www.repmus.ircam.fr/openmusic/home, [Accessed January 2011]
296 Kuuskankare M., Laurson M., *Expressive Notation Package*, In: Computer Music Journal, 2006, 30(4), pp.67–79

7 The Sonified Urban Masterplan (SUM) tool

After previously discussing existing image sonification and computer-aided composition tools, we present the *Sonified Urban Masterplan*' (SUM) tool – a tool that combines both image sonification techniques with a graphical approach to computer-aided composition towards the representation and design of the urban system.

In order to support the multiple graphical maps used in urban planning and design, the SUM tool aims to allow both the superimposition of multiple image layers and their synthesis. It will support both raster and vector images, allowing existing images to be imported for playing, as well as new drawings to be created directly within the tool.

In order to represent the multitude of spatio-temporal urban flows, it will support the co-existence of multiple paths and the independent definition of their spatio-temporal properties. These paths will be used to retrieve the data from multiple images, allowing the playing of these images as open graphical scores.

Through this multidimensional spatio-temporal approach, the SUM tool hopes to provide a common structure for both image sonification and graphical computer-aided composition – allowing both the current representation and future design of the urban system.

The SUM tool was developed in collaboration with Dr. Mika Kuuskankare, a principal developer of the PWGL environment, a widely-used Lisp-based visual environment. This environment was chosen for the SUM tool due to its graphic computer-aided composition capabilities which will support the need of the sonified urban masterplan to be used for both image sonification as well as graphical composition.

This chapter will discuss the structure of the SUM tool in terms of the sonification and compositional processes. For the interest of personal application, the following links are provided:

- The PWGL software can be downloaded here and installed accordingly: http://www2.siba.fi/pwgl/downloads.html
- The SUM tool, loaded as a library within PWGL, can be accessed here: https://www.dropbox.com/s/4n0mhz7ifkqmnon/PWGL-SUM-software-v2-5.zip
- The documentation of the SUM tool can be accessed here: https://www.dropbox.com/s/lo1xhj2cv69qluw/SUM_documentation.pdf

7.1 The Structure of the SUM tool

The SUM tool consists of three main components: images; paths; and mappers. In this section we explain each of these components and their interrelationships.

7.1.1 Images

With its main interest being the sonification of images, SUM uses images, specifically maps, as data-sources. Each image is described by a 'color-key', in which each color of interest is allocated an arbitrary numerical value, to be referenced in the sonification mapping process. SUM supports the superimposition of multiple images, which allows the synthesis of overlapping graphic information, visualizable as a '3D' matrix of data as shown in Figure 7.1. A group of data-sources is called a 'dataset', from which any number and combination of image layers may be accessed as data-sources in the mapping process.

The user organises their data as separate maps according to their attributes of interest. These maps are raster images saved at 72 PPI, allowing each map to be read as a 1:1 matrix of pixels. RGB colour format is utilized and with each data attribute allocated a colour-value, the standard colour-coding conventions in urban planning can be adhered to. With transparency retained, an empty (transparent) pixel indicates the absence of data, while a filled pixel represents its presence.

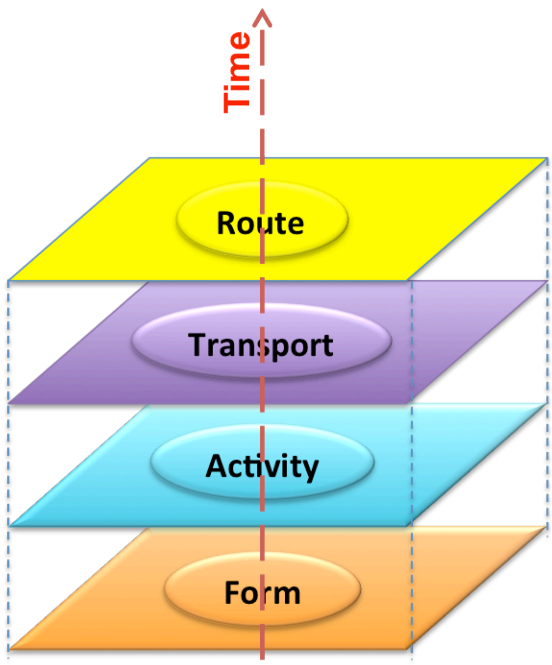

Figure 7.1: Synthesis of 2D urban data maps into one '3D' urban dataset

In the sonification of the urban system, image data-sources of interest include maps representing urban form; activities; transport infrastructure; and urban design elements. We can then combine them as a dataset to represent the urban system.

SUM allows the co-existence of raster and vector images. The flexibility of raster importation permits any visualization, including that produced by other software, to be sonified. The tool's vector drawing ability allows it to be used as a computer-aided design tool, such as Adobe Illustrator or AutoCAD. Masking also allows graphic changes to be made internally.

Thus pre-prepared maps can be imported into SUM for analysis and then modified at will, or created directly in SUM.

7.1.2 Paths

Now we describe the nature of a path in the SUM tool, which essentially will represent the urban flows themselves.

As our urban rhythms are 'path-driven', the definition of these paths is essential. In SUM, a path forms the connection between the graphical space and musical time. It is a spatio-temporal object consisting of the following qualities: location; direction; start-time; duration; and speed. The path is drawn as a vector polyline by the user over the area of interest, and then assigned a start-time and speed, either defined spatially - in metres or kilometres per second – or temporally, such as the beats per second used in music. Since an urban system consists of multiple temporal flows of different speeds, SUM supports the co-existence of multiple paths of independent speeds. This would allow the simultaneous representation of different transport modes, for example.

Paths can be used in their entirety and at a constant speed. However, SUM also allows access to the individual points of the path to control the rasterization process. Every point can be assigned an individual speed, which determines the speed of the line segment immediately following. Thus individual line segments of the same path can have different speeds.

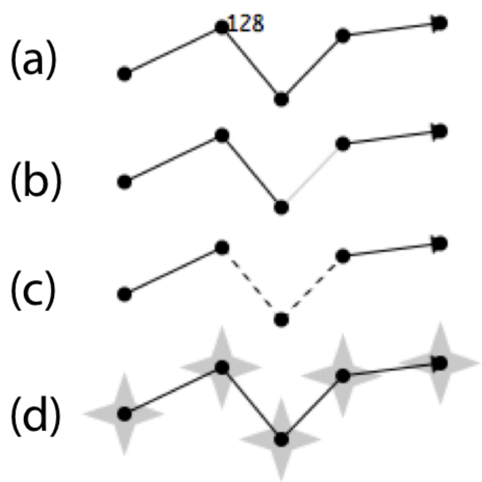

Figure 7.2: The ability to manipulate individual points of a vector time path

Figure 7.2, above, demonstrates the different ways in which the temporal structure of a path can be defined, through the manipulation of its points.

a) The speed of a specific line segment can be defined by allocating a speed to the point preceding it (in this case the second line segment is set to 128 units.) The definite speed of the line segment depends on the speed unit of the enclosing path. The points not showing speed values use the default speed set by the path.

b) Points can also be silenced (represented as faded), which means that the following line segment takes the same amount of time as a normal line segment, but no sound is produced.

c) Points can also be made 'discrete', which means that the following line segment (represented as dashed) is not rasterized at all. A discrete point skips the subsequent line segment and playback is resumed from the next non-discrete point onwards.

Finally, each point can be assigned an individual shape, as shown in *Figure 7.2* (d). The shapes are displayed instead of the standard point. Custom shapes can be created using the SUM vector Object Illustrator, allowing the user to generate a graphical composition. (see section 7.3.2 for further details)

7.1.3 Mappers

In order to translate an image data-source into sound, a mapping function must be defined. In SUM, a mapper is responsible for defining the sound output of the mapping process. It translates the graphic attributes retrieved from the image into discrete audio events, defining the sound attributes of pitch, volume, articulation and timbre. The definition of each sound attribute is independent of another. Thus one mapper can refer to multiple data-sources, as shown in Figure 7.3. A group of mappers is termed a ‘mapper-group’.

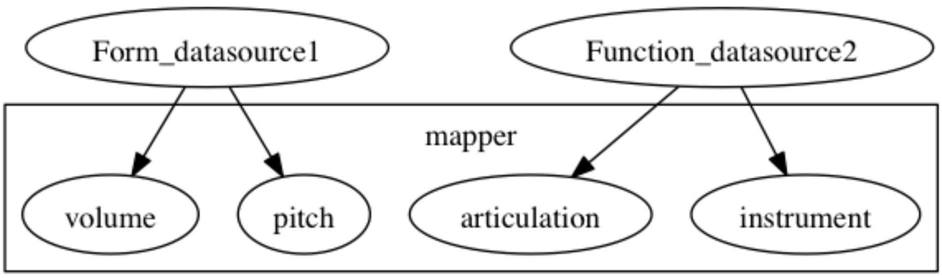

Figure 7.3: SUM mapper: example definition of sound attributes by 2 different data-sources: Form and Function

This allows different images to be used to control different audio parameters of the one sound, allowing the synthesis of multiple data-sources. For example, separate images representing the urban systems of transport, activity and morphology can be used to control the parameters of a single sound.

7.2 The SUM Mapping Process

In this section we explain the mapping process from image to sound in the SUM tool, which involves three main steps. First, graphic data is retrieved from an image data-source by a user-defined path (i.e. over the areas of interest). Then, the retrieved data is applied to a mapper, also defined by the user, for transformation into audio attributes. Finally, in order to determine the final sonification, the composition of paths and mappers must be defined.

7.2.1 Data Retrieval

The SUM mapping process is path-driven. Data is retrieved through the drawing of a vector path on an image, and the sampling of the image along this path. The vector path is rasterized according to Bresenham's line algorithm[297] in order to break it down into discrete sampling points, while retaining the order of the points to determine the direction of the path along which the time progresses. Thus for a line extending upwards and to the left, the pixels would be sampled in the order shown in Figure 7.4.

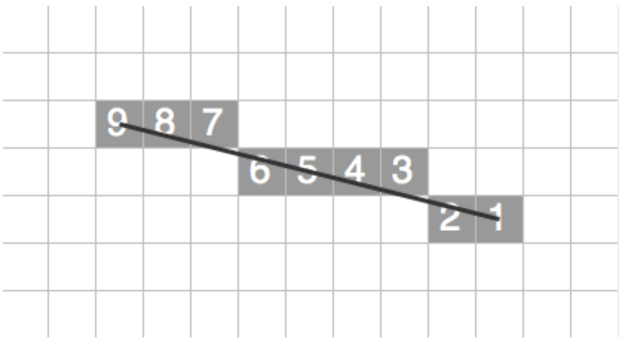

Figure 7.4: Diagram of Bresenham's line algorithm, showing sampling order

Each raster map image is then sampled pixel-by-pixel to retrieve the data of interest per each sample-point along the path. The user-defined start-time and playback speed determines the temporal structure of the mapping process. At this stage, the scale of rasterization is fixed for all speeds.

7.2.2 Parameter-Mapping

After retrieval of the graphic information along a path, these values can be applied to a mapper in order to generate the desired sound attributes of an acoustic signal (i.e. pitch, volume, articulation, and timbre, as shown in Table 7.1). The parameter-mapping process is defined by assigning a legend, from a given data-source, with a sound value. This can be implemented either directly through the graphic user interface or by using Lisp for more complicated mappings where the relationship can be defined by an algorithm.

[297] Bresenham, J., "Algorithm for computer control of a digital plotter," *IBM Systems Journal* , 1965, vol. 4, no. 1, pp. 25–30

Table 7.1: Example mapping of urban form to sound[298]

Urban Parameter	Sound Attribute
Height	Pitch
Function	Timbre
Density	Amplitude
Distance	Duration

Application of a path to a mapper produces a set of sound parameters, which can then be used to drive a wide-variety of internal or external instruments. PWGL has its own internal synthesizer as well as MIDI[299] and OSC[300] output. This allows connection to external sound synthesis engines such as Max/MSP and flexible possibilities for sound output.

Since a path and a mapper are independent of each other in terms of data-source/s, different mappings can be generated from the same set of image data-sources.

7.2.3 SUM compositional structure

Finally, in order to determine the final sonified result, the combination of path and mappers must be defined. To help define this structure, we relate the SUM sonification process to the musical compositional process, and introduce the concept of the SUM score, consisting of multiple SUM parts.

A SUM part is a sequence of audio events, the qualities of which are defined by the retrieval of data from an image with a path, and applying this path to a mapper. Thus the generation of a SUM part is a path-driven process. Application of multiple paths to one mapper will produce multiple SUM parts of the same timbral quality, but of variable temporal structure. Application of the same path to multiple mappers will produce multiple SUM parts of the same spatio-temporal quality, but of variable timbral qualities. Different combinations of paths and mappers allow the generation of numerous SUM parts from the same dataset. An example of a SUM score structure is shown in Figure 7.5.

[298] Adhitya, 2013
[299] Musical Instrument Digital Interface, http://www.midi.org/ [Accessed July 2011]
[300] Open Sound Control, http://opensoundcontrol.org/ [Accessed July 2011]

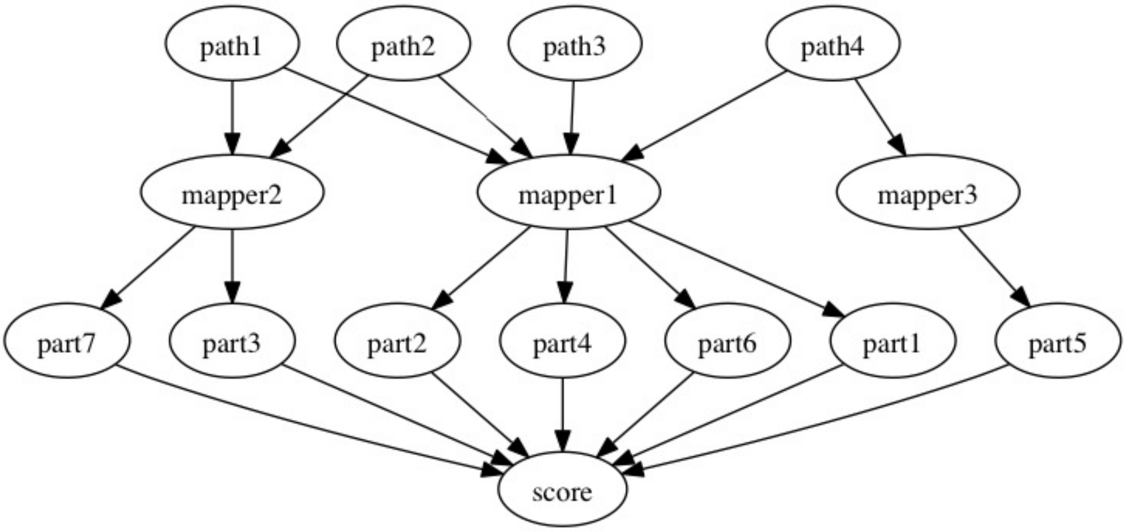

Figure 7.5: An example of a SUM score - one possible network of paths and mappers

Just like urban flows can be viewed from multiple points of view, two types of SUM scores can also be produced according to the element of interest. The playing of these paths, separately or simultaneously, allows both their comparison and their synthesis.

In order to synthesise the interrelationships between superimposed urban elements, such as activity, transport, and urban form, we can simultaneously sonify their respective image data-sources along a given path. This can be represented as a SUM score as shown in Figure 7.6.

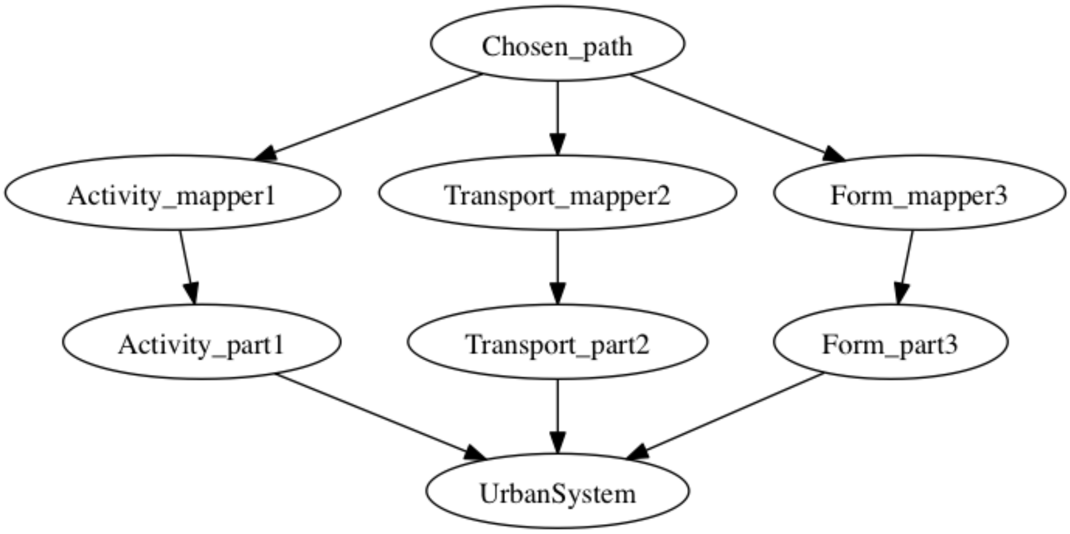

Figure 7.6: SUM score – synthesis of urban compositional elements along a chosen path

In order to compare the composition of different spatio-temporal paths of movement, we can sonify them at their respective speeds, using the same mapper and according to the same data-source/s of interest. This can be represented as a SUM score shown in Figure 7.7.

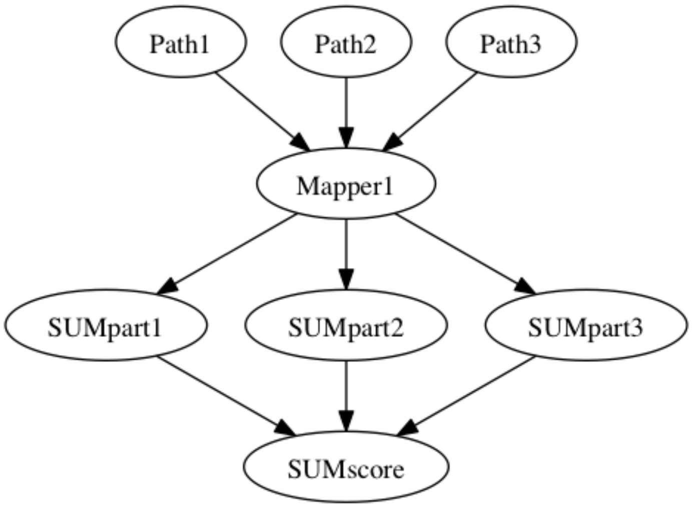

Figure 7.7: SUM score – comparison of the composition of different spatio-temporal paths

7.2.4 Application: Urban Representation

As an example, we use SUM to sonify two data maps of an area of Perth, Western Australia. After importing two raster images of urban form and urban function, we map each respectively to the acoustic attributes of pitch and timbre. In the graphic user-interface (Figure 7.8) we can only see the color-coded map representing its functions. However, due to the multi-attribute nature of sound, we can also hear the height map hidden behind it. The resulting sonification of the two maps consists of different instruments (functions) playing at different pitches (heights). The resulting piano-roll is shown in Figure 7.9.

We can then sonify the paths of interest at different speeds, to compare the urban experience using different transport infrastructure, e.g. at the speed of the car, as opposed to that of a pedestrian. The path reads all the graphical information of the selected data-sources which it traverses. Thus we can also use the SUM tool to compare and contrast the overall composition of different areas, for example, a residential street of repetitive 1-storey houses (in orange), compared to a commercial street of more varied function and form (colorful). Here we show an example of the post-industrial, zoned city of Perth, in order to compare two different types of zoning.
(Demo video: https://www.dropbox.com/s/waxe7t2vqw105au/Perth.mov)

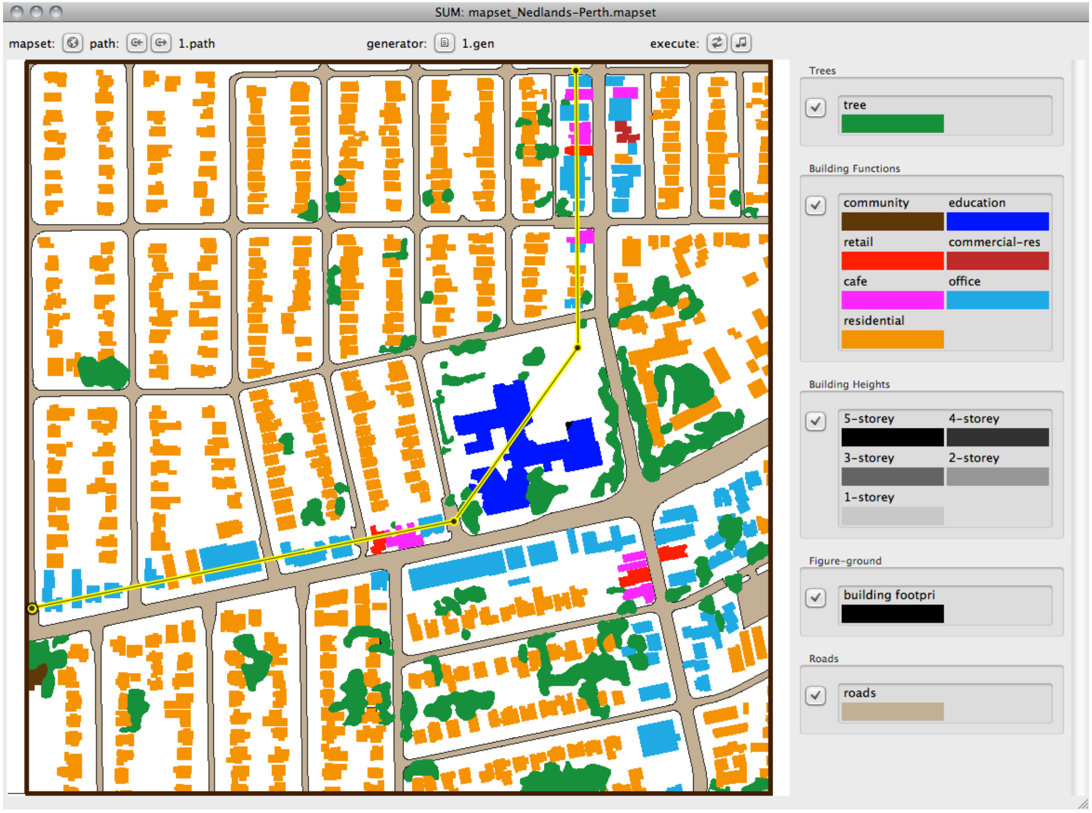

Figure 7.8: SUM tool graphic user interface showing 2 image data-sources of Perth

Figure 7.9: The piano-roll resulting from the sonification of 2 paths at a given speed

7.3 The SUM Design Process

Having demonstrated the mapping of image to sound, with the objective to represent the existing urban masterplan in space and time, we now develop the Sonified Urban Masterplan as a design tool. As explained earlier, this will allow the temporal composition of future graphic plans. Here, the SUM sonification process is reversed, with sound being mapped to image, as in computer-aided composition. To allow musical structures to inform the design process, we develop two functions of the SUM tool: i) the ability to import MIDI files as vector time-paths; ii) and the ability to draw vector objects and create a library of vector objects. These functions will allow us to generate graphical structures from musical rhythms (in MIDI format), which may then used to temporally ‘compose’ an urban design.

7.3.1 MIDI Importation

To allow both the visualisation and implementation of musical structures in the design process, SUM allows the importation of a standard MIDI file as a path layer. The MIDI tracks are converted into paths and each event in the track is converted into a point, as shown in Figure 7.10. The points have default spatial positions that are calculated according to the start times of the associated MIDI events. The time resolution, in pixels per second, can be defined by the user. By default, the events are arranged along a straight horizontal line to ensure synchronization between the tracks.

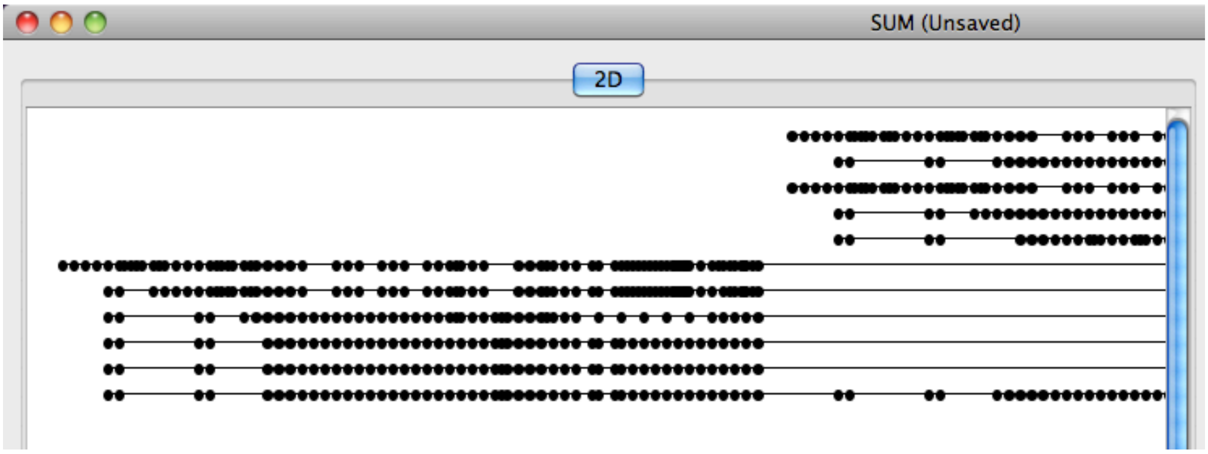

Figure7.10: The importation of a standard MIDI file as vector paths in SUM. Each track is represented as an individual path, and each MIDI event as a modifiable point along this path

MIDI paths are sonified in the same way as normal paths. The line between the points is rasterized, which defines the duration of the event attached to that point. The subsequent points are also shifted in time.

7.3.2 Object Illustrator

To support the user-definition of vector objects, SUM has a built-in ‘Object Illustrator’ - a drawing tool that can be used to create open or closed polygons, as shown in Figure 7.11.

Open polygons are generally used as paths. The shapes can be drawn using either a freehand mode or by inputting discrete points, as well as using a combination of both. A finished shape can be modified through the 'point selection mode', which allows the point handles to be manipulated by dragging. If more precise manipulation is needed, a single control point handle can be selected and repositioned by entering the exact coordinate values.

The vector objects can also be defined algorithmically. This allows for the definition of shapes/paths that are difficult to draw by hand, such as, circles or bezier curves. Every aspect of the points in the shape, in addition to the coordinates, can be controlled algorithmically.

The vector objects can then be saved with the active project or they can be saved as global shapes making them accessible from any SUM project. This permits the development of a SUM Object Library by the user, towards the generation of a personalized audio-visual language. At this stage, this Object Library is saved locally with one's SUM project file, but in the future, online collaboration may be possible.

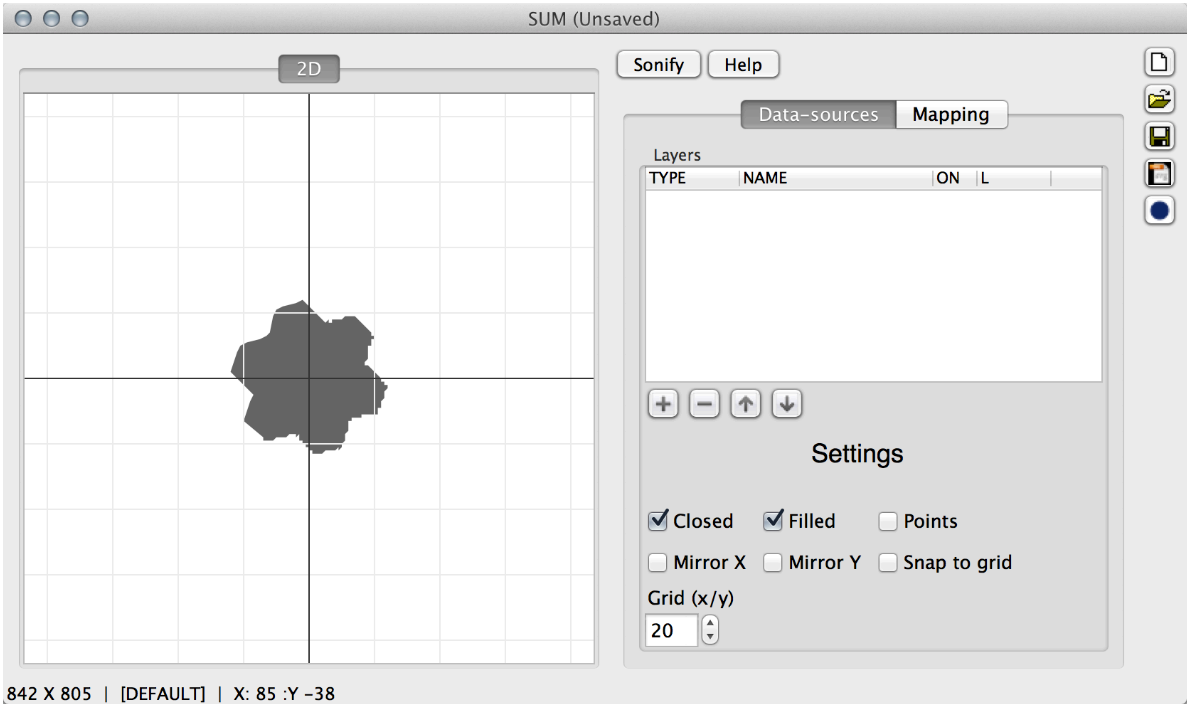

Figure 7.11: A vector object created in SUM's Object Illustrator

7.3.2 Application: Urban Design

These vector-drawing capabilities, in combination with SUM's user-defined mapping process, means that a designer is free to create his or her own graphic-sound vocabulary.

As an example, we re-design the Perth example shown in section 7.2.4, in order to change its rhythmic composition of activities. In Figure 7.12, we have drawn over the existing raster images with our vector drawing tool, changing both the colour and form of the existing buildings. By mapping the composed design elements to the same sonic legend used previously, we are able to hear the difference in composition of this area.

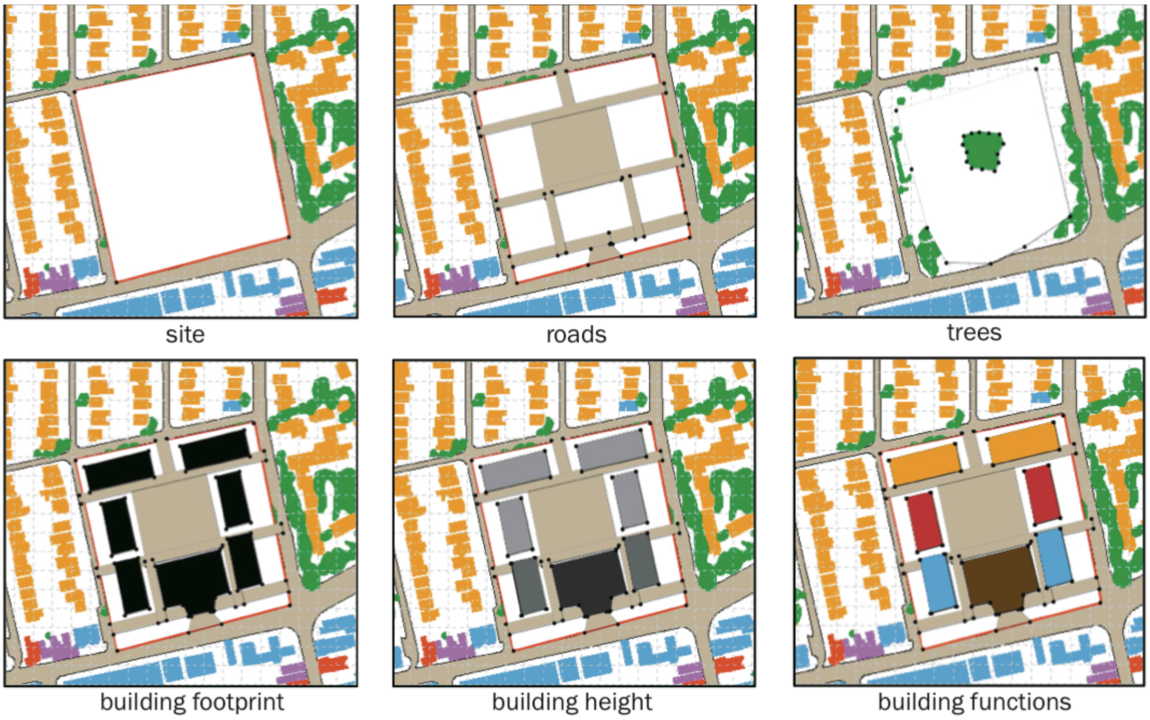

Figure 7.12: Redesigning a section of Perth using SUM's vector Object Illustrator

More details explaining how SUM can be used as a design tool can be found in *Part 4:Design,* as well as in the following paper:
https://www.dropbox.com/s/f30wrk0353ylolp/SUMDesignPaper.pdf

Conclusions: A SUM tool for Urban Sonification and Design

As seen above, the flexible structure of the SUM tool – consisting of a network of paths, vector objects, and mappers - supports both the sonification of existing images and the composition of new plans. Multiple graphic layers can be imported or generated, which can then be played back from multiple directions and speeds. Thus a multidimensional spatio-temporal masterplan can be composed, much like an open graphic score. This structure also lends itself to the audio-visual representation of the urban environment as well as other complex systems.

In the following section, we develop an Urban Sound Design Strategy for the sonification of the previously identified urban systems: transportation; activity; morphology; design; as well as the natural environment. After investigating in further detail existing sonification mapping techniques and their role in acoustic communication, we develop a series of 'Urban Instruments', which can be driven by the SUM tool in the mapping process.

8 Urban Sound Design

'I hear the rain pattering on the roof above me… I can even make out the contours of the lawn…The sound of the rain is different and shapes out the curvature for me… everywhere are little breaks in the patterns, obstructions, projections, where some slight interruption or difference of texture or of echo gives an additional detail or dimension to the scene. Over the whole thing, like light falling upon a landscape, is the gentle background patter gathered up into one continuous murmur of rain.'

John Hull[301]

The communicative power of sound can be appreciated in these words by John Hull, who although blind was able to extract a large amount of environmental information from the sounds he heard as the rain fell around him. In this chapter we attempt to harness of power of acoustic communication towards the representation of urban data. Jekosch described sound designers as '*engineers of communication*'[302] – they must take into account both how we listen and the type of information being communicated in order to be effective. Thus towards the development of an urban sound design strategy, we explore acoustic communication in further detail, including: modes of listening; semiotics-acoustics and meaning-making; acoustic dimensions and their perception; and the various ways of mapping them to data.

8.1 Communicating with sound

Effective acoustic communication involves first an understanding of how we hear - musically, ecologically, and semantically. Based on this, we can better understand *what* we hear - from 'sound objects' and 'sounding objects' to 'semio-acoustic signs' – and the auditory dimensions which can be used to design them.

8.1.1 Modes of Listening

In order to understand how we perceive our urban environment acoustically, we explore the different modes of listening used in different situations. Gaver first introduced the concept of '*everyday listening*', our auditory perception of our everyday soundscape, as opposed to '*musical listening*'. Pierre Schaeffer proposed a new mode of *'reduced listening'*, which underlies the identification of new '*sound objects*'. We explain these two listening modes below, as well the concept of semantic listening.

301 Edwards, 'Auditory Display in Assistive Technology', in *Sonification Handbook*, 2011, p.432

302 Jekosch, 2005, p.193

Musical listening

Musical listening is the way in which we consciously listen to the *perceptual* properties of the acoustic wave[303]. This means that we are concerned with '*the experience of sounds themselves*'. [304] This may include the morphology, rhythm, harmony, melody, pattern, and structure of a sound, or series of sounds, arising from their acoustic parameters of frequency, amplitude, phase and duration.[305] Thus it is concerned with the properties of the sound itself[306] and does not necessarily apply only to composed music in the traditional sense of the term.

Reduced listening – *sound objects*

Pierre Schaeffer, in his development of *musique concrete,* proposed a new mode of listening called ' *reduced listening*[307]. Here, causal (information) or semantic (meaning) connotations are supposedly 'ignored', rendering the sound an object in itself, i.e. a *sound object* [308] Neither a sound source, physical signal, a recorded sound, or its symbolic representation, it has been defined as *"the sound itself"* [309].

Ecological listening – *sounding objects*

According to the theory of ecological listening, we are able to hear physical parameters due to the sound-producing physical interactions between objects. Research by Gaver and others has demonstrated that auditory feedback can effectively convey information about a number of physical attributes of vibrating objects, such as its material, shape and size.[310] It has been shown that we can deduce a large amount of information about the cause of an acoustic event: *"Sound provides information about an interaction of materials at a location in an environment".* [311] Thus the sound of physical interactions provides much information about the type of interaction itself, and the synthesis of such '*Sounding Objects*' can be an effective way of communicating this interaction.

Everyday listening – *sound-producing events*

Everyday listening is what we use in the understanding of our everyday acoustic environments. It is based on the concept of *ecological perception,* introduced by Gaver in 1993[312] as the way in which we 'pick up' information about our surrounding environment and the interaction of objects within.[313] Gaver was to translate Gibson's ecological theory of

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[303] Grassi, Burro, 'Impact Sounds', in Avanzani, Rocchesso (eds.) *The Sounding Object*, 2003, p.48
[304] de Götzen, et al., 2008, p.407
[305] de Götzen, et.al., 2008, p.406
[306] Barrass, Vickers, in *Sonification Handbook*, 2011, p.146
[307] Schaeffer, P., *Traité des objets musicaux*, Éditions du Seuil, 1966.
[308] de Götzen, et.al., 2008, p.424
[309] de Götzen et al., 2008, p.425
[310] Avanzini, in *Sound To Sense, Sense To Sound*, 2008, p.346
[311] de Götzen et.al., 2008, p.407
[312] Gaver. W.W., *How do we hear in the world ? Explorations in ecological acoustics*, Ecological Psychology, 1993, 5(4), pp. 285–313
[313] Avanzini, 'Low-level models: resonators, interactions, surface textures', in *The Sounding Object*, 2003, p.

perception from vision to sound, in which '*we do not really perceive and recognise sounds but rather events and sound sources*'.[314] Thus everyday listening is about "*the perception of the sound-producing events".* [315] Michel Chion was to term this source identification as '*causal listening'*. [316] Expanding upon this definition, Hermann proposed the conscious act of *analytical everyday listening*: '*the conscious use of all listening skills to distinguish and analyze an object under investigation'.*[317]

Semantic listening – ***listening for meaning***

A final and very important mode of listening in the 'making of meaning' is *semantic listening*, which involves listening for the meaning of a sound. [318] The semantics of sound is concerned with the relation between the sounds and their meaning. Language and music are highly symbolic, with their meaning based on learning or memorized bindings. However, it has been observed that meaning generated by environmental and interaction sounds is much more universal. [319] Thus the use of real-world sounds is more likely to be culturally independent and universally understood. However, we can aid the meaning-making process by applying a semiotic approach to sonification, which will be discussed in the following section.

8.1.2 Semio-acoustics and 'meaning-making'

In order to understand the process of meaning-making in a sonification, we discuss the role which semiotics – '*the science of signs (and signals)'* [320]- can play in acoustic communication. According to Ute Jekosch, every acoustic event can in fact be interpreted as a sign carrier.[321] The process of understanding how we perceive and interpret acoustic events in certain ways – i.e. '*the science of auditory signs'* – is now known as 'Semio-acoustics'. Walker and Nees was to define this as the way in which *'acoustic perception takes on conceptual representation'.* [322] With the primary goal being to 'signify' data and information, we explore the different ways in which information can be 'encoded' in sound. [323]

As explained in Chapter 6, a sign is an element of communication which represents something other than itself.[324] Thus in order to understand the meaning of a sign, we must know the relationship between a signifier (the sound) and the signified (the concept). The

137-8

[314] de Götzen, et al., 2008, p.406

[315] Ibid., p.407

[316] Chion, M., *Guide des Objets Sonores, Pierre Schaeffer et la recherche musicale,* Eds. Buchet/Chastel, Paris. 1983

[317] Hermann, 'Model-Based Sonification', in *The Sonification Handbook*, 2011, p.400

[318] Barrass, Vickers, in *The Sonification Handbook*, 2011, p.146

[319] Hermann, 2011, p.400-1

[320] Ibid. based on the research of Cuddon, 1991 p. 853

[321] Ute Jekosch, Assigning Meaning to Sounds – Semiotics in the Context of Product-Sound Design. In Communication Acoustics, J.Blauert, Springer Berlin Heidelberg, 2005, p.194

[322] Walker, Nees, 2011, p.22

[323] Hermann, 2011, p.400

[324] Jekosch, 2005, p.193

types of relationships can take on various forms, ranging from analogic to symbolic as shown in the representation continuum defined by Kramer in Figure 8.1.[325]

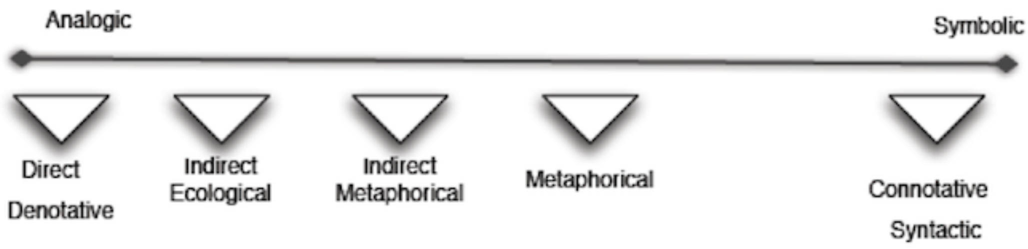

Figure 8.1: Analogic-symbolic representation continuum[326]

This acoustic representation continuum ranges from analogic to symbolic.[327] *Analogic* representation means that the most direct and intrinsic relationship to its referent, e.g. the causability drawn between the geometric shape of an object and its vibrations, usually acquired through experience. *Symbolic* representation, on the other hand, means that there is an arbitrary association between the sound and its referent, which needs to be learnt.

In relation to environmental sounds, Keller and Stevens (2004) were to categorise signal-referent relationships into three categories: direct, indirect ecological, and indirect metaphorical.

1. *Direct* relationships, in which the sound is ecologically attributable to the referent.
2. *Indirect ecological* relationships, in which the sound is ecologically associated with, but not directly attributable to, the referent.
3. *Indirect metaphorical* relationships, in which the sound signal is related to its referent only in some emblematic way.

The concept of *indexicality,* first applied to sonification by Vickers and Hogg, allows us to measure the arbitrariness, or closeness, of a mapping to its data. High indexicality means that the sound is directly related to the data, i.e. through a direct data-to-sound mapping. Low indexicality indicates more symbolic or interpretative mappings.[328] In order to compose more intuitive sonifications, we aim to increase the indexicality of our approach. Thus with reference to environmental sounds, we will attempt to utilise *direct* mappings between our assigned sound and its referent data in the first place, before drawing on indirect ecological relationships.

Metaphors and Metonyms

Metonyms and metaphors use cultural associations to generate meaning by connotation. A *metonym* invokes an idea or object by some detail or part of the whole, whereas a *metaphor* expresses the unfamiliar in terms of the familiar. [329] Convincing metaphors have been noted

[325] Kramer (1994) in Walker, Nees, 2011, p.22
[326] Walker, Nees, 2011, p.22
[327] Walker, Nees, p.23
[328] Barrass, Vickers, 2011, p.157
[329] de Götzen, et.al, 2008, p.418

to significantly increase effectiveness.[330] Ideally, they require little explanation, fulfil user expectations, and are convincing as well as aesthetically pleasing.[331]

Aesthetics

Last but not least, in the goal towards meaning-making, we should not forget the important role of aesthetics. While the separation has often been made between aesthetics and function in the design process, aesthetics has shown to play an important part in the making of meaning.[332] According to Tractinsky et al., '*What is beautiful is usable'*.[333] Susini et al. also observed that it improves the perceived usability of an auditory interface.[334] Aesthetics is in fact now considered an integral part of sound design, just as form is a part of design.[335] Just as in graphical visualization, aesthetics can help play a role in designing sonifications which can effectively communicate the data in question.

8.1.3 Forming audio-(visual) objects

The concept of *"Auditory objects"* was first introduced by Bregman, and is important in the cognition of sound objects and polyphony. An '*object'* is traditionally being defined as 'a material thing that can be seen and touched'.[336] In order to cater for the auditory domain, psychologists Kubovy and Van Valkenburg (2001) were to introduce a more holistic definition: *"A perceptual object is that which is susceptible to figure-ground segregation"*[337]

The concept of '*figureground segregation'* is based on the Gestalt laws of grouping, and reliant on our ability to segregate and perceive groups, whether it be a sequence of notes as a melody, or spatial patterns in a field of objects.[338] Thus object formation is reliant on our ability to perceive groups. We summarise the conditions for such *auditory stream segregation* below:

- *Tempo:* The faster the tempo, the more likely different streams will be perceived.[339]
- *Frequency:* Thus greater the frequency separation, the greater the independence of two streams.[340]
- *Timbre:* Sounds are grouped according to similarity. Use different musical groups to separate data types.
- *Loudness*: Loudness level has a more subtle grouping effect, although similar sound

[330] Bovermann, Rohrhuber, de Campo, in *The Sonification Handbook*, 2011, p.240
[331] Neuhoff, in *The Sonification Handbook*, 2011, p.106
[332] Barrass, Vickers, 2011, p.149, research of Rodney Berry and Noatoshi Osaka (2002)
[333] Tractinsky N, Katz A, Ikar D (2000) What is beautiful is usable. *Interact Comput* 13:127–145
[334] P. Susini, N. Misdariis, G. Lemaitre, O. Houix, « Naturalness influences the perceived usability and pleasantness of an interface's sonic feedback », JMUI, vol. 5, n° 3, 2012
[335] http://pds.ircam.fr/906.html [Accessed May 2013]
[336] *Oxford English Dictionary* [Online], Oxford University Press, http://oxforddictionaries.com/definition/english/object?q=object [Accessed February 2013]
[337] Kubovy, 2010, p.102
[338] Ibid.
[339] Neuhoff, 2011, p.76
[340] Ibid., p.76, research of Bregman, 1990

levels tend to group together. [341]

- *Spatialisation:* Sounds can be grouped according to the location of their source.

Through auditory stream segregation, we can see how multiple data sets can be mapped polyphonically to sound and heard as discrete data streams.[342] However, attention should be paid to avoid interference of grouping effects. For example, the grouping effect of pitch can be counteracted by differences in timbre. [343]

Forming audio-visual objects

As we are concerned specifically with the sonification of images in the playing of our masterplan, we are interested in the formation of audio-visual objects. According to Kubovy's *Theory of Indispensable Attributes* (TIA), space is indispensable for vision, while frequency is indispensable for audition. Time is an indispensable attribute for both.[344] In the formation of an audio-visual object, binding of separate audio and visual information must occur, as shown in Figure 8.2. The binding of an acoustic event and a visual event is dependent on the *ecological fit* between visible events and sounds i.e. the plausibility of their cause. In the case of more arbitrary sounds and visual events, synchrony is necessary.[345]

Thus, in our proposed sonified urban masterplan, we aim to synchronise the audio and visual representations of the articulated rhythms. The graphic intersection between a flow and a form will be articulated with sound, resulting in binding and the representation of urban rhythm as an audio-visual object. Furthermore, we will aim to capitalise on our ecological listening abilities in order to promote binding.

[341] Ibid., research of Hartmann & Johnson, 1991; Van Noorden, 1975
[342] Grond, Berger, 2011, p.380
[343] Neuhoff, 2011, p.76, (research of Singh, 1987)
[344] Kubovy, 2010, p.10
[345] Schutz, M & Lipscomb, S., 'Hearing Gestures, Seeing Music: vision influences perceived tone duration.' *Perception* 36 (6), 2007, pp. 888-897

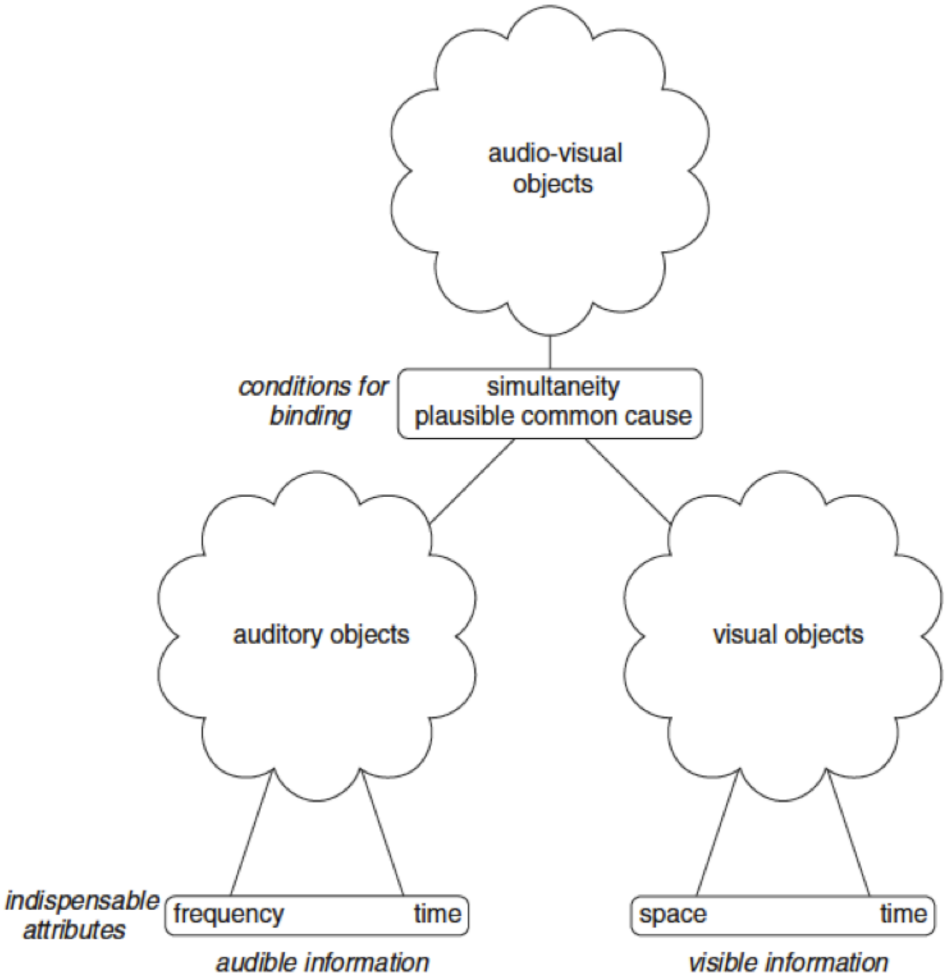

Figure 8.2: Kubovy, Formation of audio-visual objects[346]

8.2 Sonification Mapping Strategies

According to Barrass and Vickers, *'Any time something is represented in a form external to itself, a mapping takes place'*.[347] Sonification involves the mapping of data source(s) onto acoustic parameters. [348] The acoustic result is obviously dependent on the applied mapping function. Here we explore the dimensions of the mapping process in order to generate an effective sonification.

The mapping of data to sound involves the meeting of two processes of very different natures – the objectivity of the data input and the subjectivity of human perception. [349] Thus an effective mapping function must translate data parameters into signal parameters, while

[346] Kubovy, M., Schutz, M., 'Audio-Visual Objects', *Review of Philosophy and Psychology*, March 2010, vol.1, issue 1, p.59
[347] Ibid.
[348] Walker, Nees, 2011, p.22
[349] Hermann, 2011, p.366

achieving a 'perceptually valid result'. [350]As noted by Walker and Nees, *'sonification designers need to be aware that not all mappings are created equal'.*[351]

A mapping function depends on the auditory structures being mapped, which can be described by different *'auditory dimensions'*. Three levels have been identified:

I. low-level audio structures
II. mid-level musical structures;
III. high-level expressive features.[352]

The three main low-level physical auditory dimensions are: frequency; amplitude; and spectrum. These correspond to the most commonly used *perceptual auditory dimensions* of pitch, loudness and timbre, which includes brightness.

In our development of an effective urban mapping strategy, we will first explain these low-level perceptual auditory dimensions, before investigating higher-level iconic mappings involving the use of natural or mechanical sounds, to more 'abstract' mappings, as employed in music.

8.2.1 Perceptual Auditory Dimensions

'*…the subjective perceptual experience of a particular physical characteristic of an auditory stimulus'*.

Neuhoff[353]

The three perceptual auditory dimensions are pitch, loudness and timbre. Their effective mapping involves a consideration of both polarity and scaling, particularly due to the non-linear nature of auditory perception.

Polarity is the directional mapping (increasing of decreasing values) of data to a sound parameter. Care must be taken to 'go with the flow'.[354]

Scaling of data is important in order to maximize the effectiveness of the perceptual range of each auditory parameter. [355] Auditory sensitivity varies across the range of different auditory dimensions. [356]

Pitch

Pitch is frequently used to represent data advantages as it is easily mapped and easily

[350] Ibid., p.368
[351] Walker, Nees, 2011, p.24
[352] Camurri, A., in *Sound to Sense, Sense to Sound*, 2008, p.248-250
[353] Neuhoff, 2011, p.63
[354] Grond, Berger, 2011, p.385
[355] Ibid.
[356] Ibid., p.387

detected. However, polarity and scaling can vary across the data dimensions being represented. [357] For example, while we can hear over 10 octaves, we can better discriminate differences between in the middle range. [358]

Loudness

Loudness corresponds to the perception of the amplitude of an acoustic signal. While being quite easy to control and understand, it has shown to be a much poorer indicator of continuous data sets than pitch. [359] Research has shown that our discrimination, and memory, of differences in intensity is much less effective than for frequency. Furthermore, its effectiveness is influenced by the conditions of the user's environment. This makes the use of loudness change as a representation of continuous datasets difficult.[360] While it can be used for discrete changes of state, its application to represent absolute data values is difficult. [361]

Timbre

Due to the absence of a perceptual metric for timbre[362], this perceptual acoustic parameter is often defined by what it is not: *'...that attribute of auditory sensation in terms of which a listener can judge that two sounds, similarly presented and having the same loudness and pitch, are different'*.[363]

While timbre can be highly effective in revealing differences in data, since the distance between two timbres cannot be quantified, it is difficult for timbre to represent detailed data. [364] Rather, it is restricted to broad categorization and used as both a continuous and a categorical dimension. Thus timbre can be an effective auditory dimension for sonification. However, it is important to choose easily discriminable timbres as *'using similar timbres can lead to confusion due to undesirable perceptual grouping'.*[365]

Brightness

A component of timbre, brightness is defined as '*the balance between the upper and lower partials of a sound spectrum'.*[366] It is also identified as the spectral centroid of the sound - 'the center of gravity of the frequency distribution' of a spectrum.[367] The brightness of the sound is determined by the proportion of high to low frequency energies[368], with the higher

[357] Neuhoff, 2011, p.63
[358] Grond, Berger, 2011, p.388
[359] Neuhoff, 2011, p.66
[360] Ibid.
[361] Ibid., p.67
[362] Grond, Berger, 2011, p.388
[363] American National Standards Institute ANSI
[364] Grond, Berger, 2011, p.388
[365] As observed by Flowers (2005), in Neuhoff, 2011, p.68
[366] Bregman (1990) in Barrass, S., 'A Perceptual Framework for the Auditory Display of Scientific Data', *ACM Transactions on Applied Perception*, Vol. 2, No. 4, October 2005, pp. 394
[367] Widmer et al., in *Sound to Sense, Sense to Sound*, 2008, p.166
[368] Cook, Sound Synthesis in Auditory Display, in *The Sonification Handbook*, 2011, p.207

frequency energies generally producing a 'brighter' sound. It is also recognized as a very effective perceptual acoustic parameter in stream segregation.[369]

Interaction of parameters

The low-level perceptual acoustic dimensions of pitch, loudness, timbre and brightness, can each be used separately in data sonification, with various degrees of representation, as described above. However, when used in combination, for example in the sonification of multi-variate data, these perceptual dimensions can interact with each other. For example, changes in one dimension (e.g. pitch) can affect perceived changes in others (e.g. loudness).[370] These interferences must be taken into account. Kramer was to recommend that data be mapped to perceptual parameters that do not interact.[371]

On the other hand, when mapped to a single data variable, the interactions of multiple perceptual dimensions can be used to enhance the salience of important data changes.[372] For example, increasing loudness can be used in combination with increasing pitch, in order to enhance the perception of an increase in data.[373] However, this is more adapted to situations concerned with changes and trends, rather than absolute values.[374]

A Timbre-Brightness-Pitch (TBP) space

Timbre, brightness, and pitch are recognized as important perceptual auditory parameters in sequential stream integration.[375] In order to understand the relationship between them, Barrass was to propose a Timbre-Brightness-Pitch (TBP shown in Figure 8.3b) model based on the Hue, Saturation, Lightness (HSL shown in Figure 8.3a) model used to display color.[376]

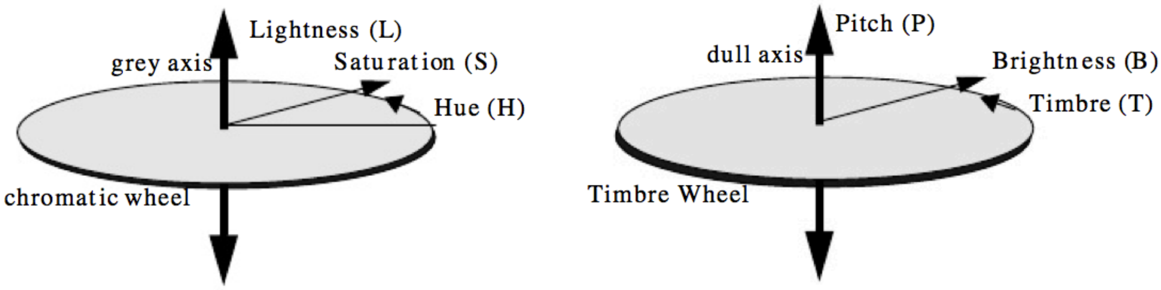

Figure 8.3: a) The HSL color model vs. b) the TBP sound model[377]

[369] Bregman (1990), Barrass (2005)
[370] Neuhoff, 2011, p.68
[371] Kramer (1994), in Barrass, 2005, p.390
[372] Ibid., p.69
[373] Ibid., p.67
[374] Ibid., p.70
[375] Bregman (1990), Barrass, 2005, p.400
[376] Barrass, S., A Naturally Ordered Geometric Model of Sound Inspired by Colour Theory, in *Proceedings of Synaesthetica*, 1994, Available at : http://www.academia.edu/308248/A_Naturally_Ordered_Geometric_Model_of_Sound_Inspired_by_Colour_Theory, [Accessed January 2013]
[377] ibid.

The 'color chooser' tool is represented graphically as a color wheel of different hue sectors, with the radius representing the degree of saturation, and lightness as the vertical axis. Correspondence is drawn between the dimensions of color, and those of sound, in order to develop a 'sound chooser' tool of a similar geometry (as shown in Figure 8.3). Being qualitative and categorical, timbre is mapped to the sectors of a wheel according to their similarity. The most dissimilar timbres are placed the furthest apart, forming a Timbre Circle. Brightness is represented in radius, like saturation, and pitch, expressed vertically like lightness.[378]

The TBP model visually shows the relationships between these qualitative perceptions, and as such provides a means of choosing sounds for an effective sonification. E.g. sounds of opposite timbres and large pitch separation would achieve the greatest perceptual difference in a sonification. We will attempt to use these differences in order to improve identification of our urban sonic code.

8.2.2 Iconic Mapping

'*We know that simply mapping a sound that has a clear environmental referent…to a particular display dimension increases user response time and accuracy in the display over more arbitrary mappings'.*

McKeown & Isherwood[379]

As explained previously, auditory icons draw upon our familiarity with sounds from our everyday experience of the real world. Sounds should be easily identifiable while context should be respected.

Mapping to changes in real world auditory events is a common technique for auditory icons. They can be effective in the sonification process due to changes in such auditory events tending to be more familiar and easier to identify than changes in simple acoustic dimensions. [380]

The identification of sounds can be assessed based on listening tests [381] and potential semantic links can be investigated through *EarBenders,*[382] a task-oriented approach developed by Barrass for auditory display design. Based on the Task analysis and Data characterisation (TaDa) approach used in human-computer interaction (HCI) design, user-oriented storyboards, case-studies and interviews are used to build a database of task-significant everyday sounds, towards the development of metaphors.[383] Suitable sounds can

[378] Barrass, 2005, p.392
[379] Ibid., p.81, McKeown,D., Isherwood,S., 'Mapping candidate within vehicle auditory displays to their referents'. In *Human Factors*, 2007, 49(3), pp.417–428.
[380] Neuhoff, 2011, p.79, Neuhoff and Heller (2005)
[381] Measure of Causal Uncertainty, similarity ratings/scalings
[382] The research of Barrass and Erickson, in Brazil, Fernstrom, *Sonification Handbook*, 2011, p.3
[383] Barrass. S., *TaDa! Demonstrations of Auditory Information Design*, CSIRO Division of Information Technology, 1996

then be searched for according to the specified user, display-type and information.[384]
Auditory icons can be as simple as recordings of everyday sounds that metaphorically represent user actions. However, the constant playback of a recording is potentially annoying as well as limited in the information it can convey. For a greater level of detail, such as the representation of levels, parameterization can be applied using multiple recordings or varied synthesized sounds. The most expressive form of auditory icons allows continuous representation of interactive gestures or complex processes.[385]

Parameterization

As everyday sounds are often able to communicate multiple dimensions simultaneously, parametric auditory icons can also be created, e.g. changing sizes of objects, variations in loudness, playback speed (and therefore pitch). Audio file playback can be processed to represent objects and events of different size and distance. However, the amount of processing is restricted to avoid losing identification. Multiple recordings of the same event with changed parameters can also be used.

An iconic approach to sonification has proven to give good identification performance with very little training, due to the "intuitive" mapping between the sound and the data. However, it is not always possible to identify suitable sounds for all the information to be represented. In such cases, an earconic approach may be more suitable, based on musical mapping processes.[386]

8.2.3 Musical mapping

'It is important to keep in mind that western music notation evolved over centuries in response to progressive refinements and changes in musical textures, timbre, pitch and rhythmic attributes.'

Hermann[387]

The sonification mapping process can be compared to that of musical composition, where the 'mapping' is similar to instrumentation or orchestration. Both rely on low-level perceptual auditory dimensions - a musical note represents pitch rather than frequency; and the same pitch played by two instruments is heard as the same note played with a new timbre rather than two discrete sounds.

Thus an effective mapping strategy can be based on existing musical models, which are already well-tempered and scaled. Rather than mapping data to arbitrary changes in frequency, we can map to musical scales that provide an aesthetically-pleasing structure.[388]
This, of course, is highly dependent on cultural context, which often have their own cultural

[384] de Gotzen et al., 2008, p.418
[385] Ibid., p.335
[386] McGookin, Brewster, Sonification Handbook, 2011, p.350
[387] Hermann, 2011, p.369
[388] Walker, Nees, 2011, p.25

musical scales. However, as noted by Hermann, sonifications must not lose sight of their 'ultimate purpose': '*to map and represent data rather than musical ideas.'*[389]

Composing Earcons

As described earlier, Earcons are *'short, structured musical messages, where different musical properties of sound are associated with different parameters of the data being communicated.'*[390] Thus they can be considered a 'musical' form of sonification.

Their function can be seen as similar to musical '*motives*': *'brief succession of pitches arranged in such a way as to produce a tonal pattern sufficiently distinct to allow it to function as an individual recognisable entity."*[391] Similar to their implementation in music, they can be manipulated through changes in timbre, dynamics and register to systematically alter their meaning and form a taxonomy of signs.

Earcons should be both recognisable and identifiable, and studies have shown that this can be increased by maximizing the difference between the auditory attributes of different Earcons. It is suggested by Brewster, Wright and Edwards that:

- *Timbre* should be easily distinguishable and come from different musical families
- *Rhythm* should be strongly dissimilar, and is even more effective if combined with pitch
- *Pitch* structures should be contrasting, and if register is used, of at least two or three octaves difference
- *Loudness* is not distinguishing enough and should not be used on its own[392]

8.2.6 A Rhetorical Approach

Last but not least, a rhetorical approach to sonification was recently introduced by Polotti et al., in order to *'strengthen the structural coherence of a sonification, but also to build the basis for its semantic effectiveness'*.[393] They explored the use of rhetoric in the sound design of computer operating system functions.

Polotti et al. first examine the use of rhetoric of 16th-18th century western music, and its structural links to verbal discourse, particularly in terms of its temporal disposition: *'Musical rhetoric becomes, thus, useful for organizing the syntax of a piece, in order to make it semantically effective and able to successfully arousing communication by correctly addressing both the logical and emotional spheres of the listener.'*[394]

Rhetoric is also a major communication technique employed in cartoons, which draw on the

[389] Hermann, 2011, p.369
[390] McGookin, Brewster, 2011, p.339
[391] de Götzen et al., 2008, p.404-5, research by Blattner et.al.
[392] McGookin, Brewster, 2011, p.345
[393] Polotti, P., Benzi, C., Rhetorical Schemes For Audio Communication, *Proceedings of the 14th International Conference on Auditory Display,* Paris, France, June 24-27, 2008, p.2
[394] Polotti, Benzi, 2008, p.2

use of non-verbal sounds for semantic communication: '*The principle of reduction and emphasis makes the sound materials of cartoons easy to analyze according to rhetorical figures*.' [395]

Drawing on these two sources, a set of rhetorical figures was developed and then tested for their effectiveness in communicating the functions, compared to non-rhetorical techniques. Preliminary results show that *'even if the rhetorical figures are not self-evident on their own at an unconscious level, after a verbal explanation, they become a strong identifying element that can be extremely helpful for memorization tasks.'* [396]

This suggests the potential for rhetoric-based sound design guidelines to improve semantic understanding, usability and learnability in future Auditory Display and Sonic Interaction Design.

Conclusions: Towards an effective sound design strategy

From the variety of ways of listening, the range of semio-acoustic techniques, the multitude of acoustic dimensions and their perceptual counterparts, and the numerous ways of mapping them to data, the complexity of acoustic communication is evident. There is no simple solution as each case has its own objectives for communication. In general, iconic representation has shown to be effective when the information is physically related to the reference sound sources, exploiting our everyday physical experiences in interpreting the sounds.[397] However, if the data are not immediately associable with sounding objects, more abstract representation may be necessary. In this case, musical models provide an aesthetically pleasing structure for meaning making. A rhetorical approach can also aid semantic communication and learnability of earcons and icons. Each sonification approach has its advantages, and an effective sound design often involves a compromise between precision, intuitiveness, and aesthetics.[398]

[395] ibid.
[396] ibid., p.6
[397] de Götzen, et.al., 2008, p.412
[398] Hermann, 2011, p.364

8.3 SUM Urban Sound Design

Based on the above exploration of effective acoustic communication, we now develop our sound design strategy for the mapping of each urban data-source into audio parameters. In the sonic representation of each urban system, we draw upon the iconic, abstract and musical representation techniques previously explored, according to the nature of each element of interest: the natural environment; urban morphology; transport infrastructure; activity distribution; and urban design objects. We approach our sound design strategy at two hierarchical levels: first, at the overall level of each urban system; and second, at the level of the individual elements within them.

8.3.1 A hierarchical approach

Level 1: Instrumental sections

At the first hierarchical level, the different urban systems are characterised like the different sections of an orchestra - by their mode of sound production and the resulting timbre. Each urban system - transportation, outdoor environment, indoor activities and urban design elements – is related respectively to the orchestral sections of strings, brass, woodwind and percussion (Table.8.1). The result is a set of 'Urban Instruments' which together form an 'Urban Orchestra'.

Table 8.1: Relationship between each urban system and instrumental section

Urban System	Instrumental Section
Environment	Brass
Transportation	Strings
Urban Activities	Woodwind
Urban Form	Tuned Percussion
Urban Design	Percussion

To synthesise the sound of each urban system, we developed a series of '*Urban Instruments'* described as follows:

vi. *Environment player* – for the synthesis of natural environment and public open space
vii. *Transport player* – for the synthesis of transport infrastructure
viii. *Activity player* – for the synthesis of indoor activities
ix. *Urban form player* – for the representation of building height and length
x. *Urban design player* – for the synthesis of urban design 'sounding objects'

These Urban Instruments are designed to be driven by the SUM tool through the mapping of each urban dataset to sound parameters. The urban parameters of height, intensity and length have been mapped to the audio parameters of pitch, loudness and duration respectively, as shown in Table 8.2 below. They are based on physical models according to their mode of sound production. For aesthetic reasons, the instruments (and thus their generating sound files) are tuned to the same tonality of C. These instruments will be used in Part 2 in the sonification of our case-study city of Paris.

Table 8.2: Parameter-mapping of urban parameters to audio parameters

Urban Data-source	Audio Parameters			
	SUM Instrument	**Pitch**	**Loudness**	**Duration**
Environment	***Soundfile + plate***	Ground level	Intensity	Distance
Transport	***Soundfile + chord***	Elevation	Intensity	Length
Activity	***Soundfile + tube***	Floor level	Intensity	Length
Form	***Vibrating plates***	Height	Density	Length
Function	***Soundfile + tube***	Floor level	Intensity	Length

Level 2: Individual instruments

Just like within each instrumental section, where each instrument has its own characteristics, within each urban system, each urban element has its own acoustic signifier. For example, a 'park' within the Environment section sounds different to a 'river', even though both have been generated using the same technique. In the development of our individual auditory signs, we start from the most direct semio-acoustic relationship to the least, from the most symbolic to the most abstract. Where the urban element in question has a symbolic sonic output, an iconic sound recording is used. For example, the sound of water in the case of the river draws on our ecological listening. In the case where these elements do not have an associated sound, the idea of creating a 'sounding' object based on their physical or material properties is used as a metaphor. For example, a light is given a bright, high-pitched sound. Overall, a combination of symbolic and more abstract sounds are employed, creating yet another level of distinction. In general, the environmental, transport and activity-based systems use auditory icons, whereas sounding objects are used to represent urban form and design elements.

8.3.2 Instrument Implementation

The instruments have been developed in MaxMSP, a commonly-used visual programming language for computer music.[399] They are based on physical modelling principles and utilise the Modalys[400] objects developed by Ircam. They are then controlled by the SUM tool via Open Sound Control (OSC)[401] data import of the parameters of instrument, pitch, velocity, duration, and articulation. The sound design approach to each urban system is explained below. Individual demo videos are provided or the whole code can be viewed here: https://www.dropbox.com/s/ombpjyqw07k99u7/SUMpart2_UrbanSonicCode.mp4 Further implementation details can be found in *Appendix 2: SUM Urban Instruments.*

[399] http://cycling74.com/products/max/
[400] http://forumnet.ircam.fr/product/modalys/?lang=en
[401] *Open sound control* (OSC), Available from : <http://opensoundcontrol.org/introduction-osc>

8.3.3 SUM Urban Instruments

Environment player

(Demo video: https://www.dropbox.com/s/8pbjvao4a7kxby4/SUM_ambience2.mp4)

The *SUM Environment player* (Figure 8.3) is used to sonify elements of the natural environment, including water, parks and gardens. The sonification is synthesised by a brass plate vibrated by an iconic sound file. This is aimed to give an impression of an external surface while appealing to our ecological listening. A similar player (Figure 8.4) was also developed for the synthesis of public urban spaces, such as markets, places and playgrounds.

Transport player

(Demo video: https://www.dropbox.com/s/hrfd3f0mrjh1fm8/SUMtransport2b.mp4)

The *SUM Transport player* (Figure 8.5) consists of the vibration of a chord by an iconic sound file. The strings are chosen as an analogy to the linear nature of transportation. We use the symbolism of a sound recording but characterise the sounds by timbre. The volume of each mode of transport can be adjusted to reflect its importance or the intensity of its usage.

Activity Player

(Demo video: https://www.dropbox.com/s/8n0z2avj9bdku1x/SUM_activity.mp4)

The *SUM Activity player* (Figure 8.6) is intended for the representation of internal urban activities. It operates as a woodwind instrument played by an iconic sound file. This is aimed at allowing the iconic activity sound recordings to resonant within the instrument, giving a sense of interiority as these activities take place on the inside of buildings, as opposed to the external activities which take place in the public open space. Pitch is mapped to the floor of the activity, in a similar way to the height of urban morphology below.

Urban Form Player

(Demo video: https://www.dropbox.com/s/8n5yu93oh8dus04/SUM_urbanform.mp4)

The *SUM urban form player* (Figure 8.7) sonifies urban form by using white noise to vibrate a plate tuned to the height of the form. Thus pitch is calculated from the ground plane (default set at middle C), by adding the height of the building, in metres or floors, where 1 metre is equal to 1 semitone, and 1 floor equal to 3 metres. The duration of a note is determined by the length of the built form, depending on the speed of travel.

Urban Design Player

(Demo video: https://www.dropbox.com/s/8asv20au7tc0uxn/SUM_UDplayer.mp4)

The *SUM urban design player* (Figure 8.8) is based on the principle of sounding objects. As these static urban design elements do not normally make noise without an external interaction, the analogy of 'hitting' each object is used in order to 'play' it. Pitch is used to reflect the approximate height of the element as previously used. Furthermore, each sound object is of a different timbre/ brightness according to the material of the object.

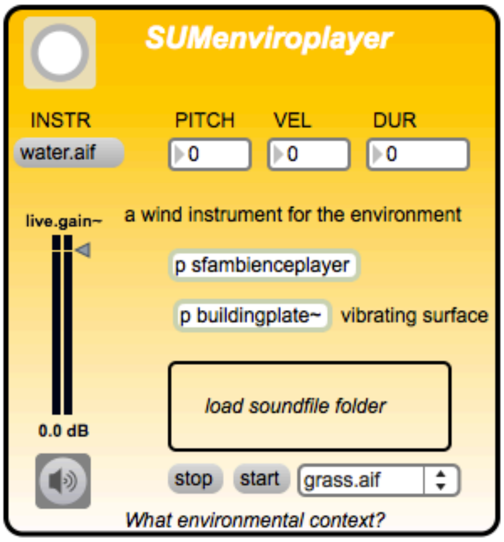

Figure 8.3: SUM environment player

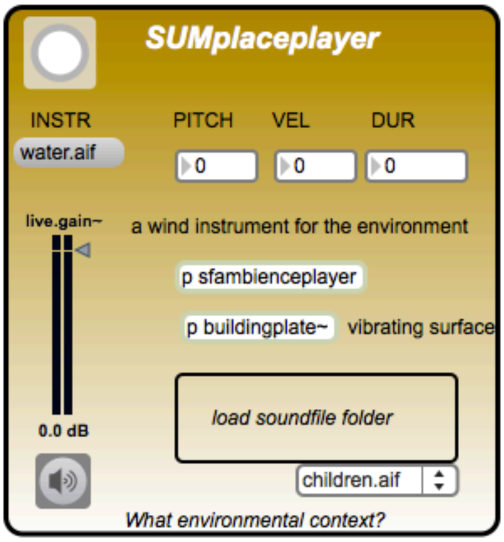

Figure 8.4: SUM place player

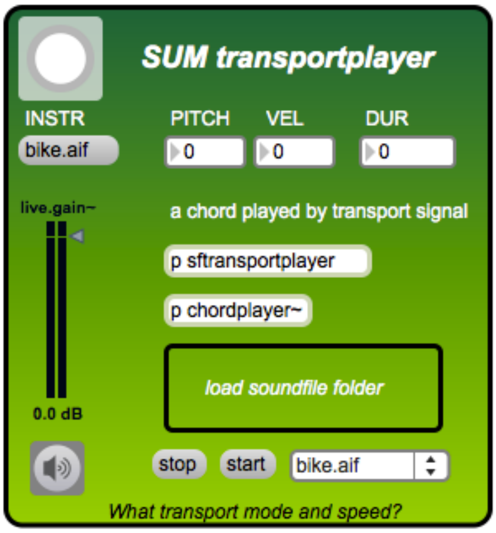

Figure 8.5: SUM transport player

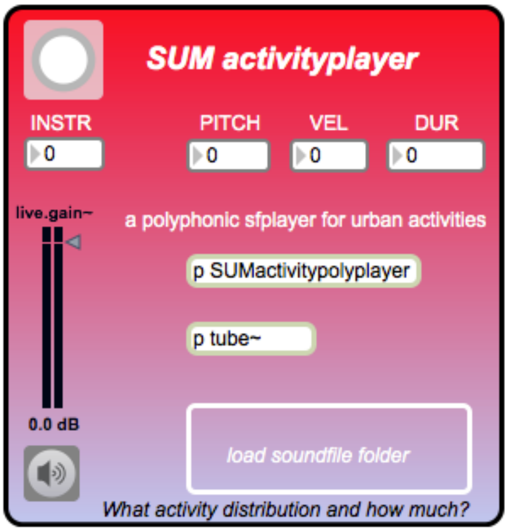

Figure 8.6: SUM activity player

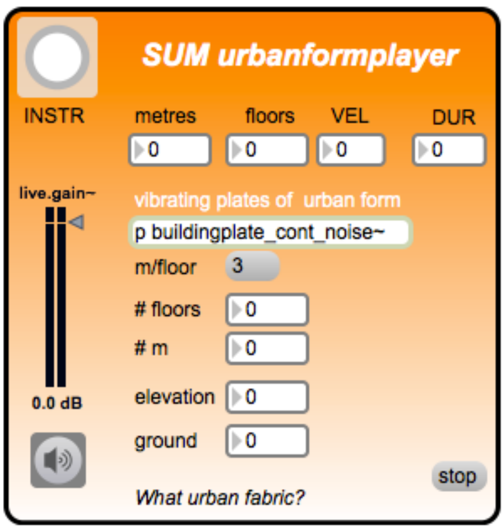

Figure 8.7: SUM urban form player

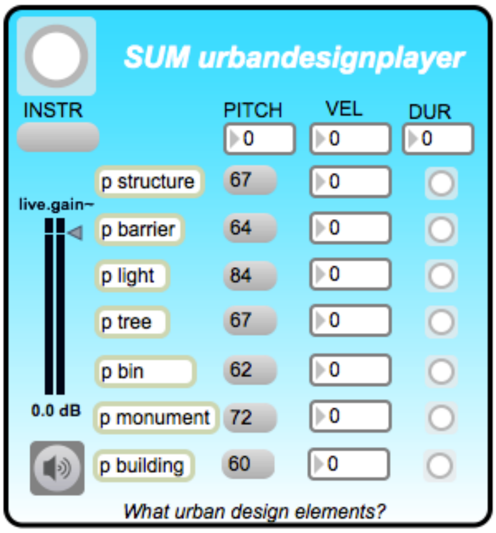

Figure 8.8: SUM urban design player

part 3

Listening to Urban Rhythms

Introduction

In the previous Part 2, we developed a Sonified Urban Masterplan (SUM) tool and developed a set of SUM instruments. In Part 3, we explore the application of the SUM tool in the representation of urban rhythms.

First, we apply our Urban Sonification Strategy to our case-study city of Paris, generating a set of sonified urban maps of the city which allow us to listen to its various urban rhythms. We use the SUM tool to sonify the following urban datasets of interest: transport; urban form; activity; and urban design. We then apply our generated Urban Instruments of Part 2 to synthesise the sounds. The result is a Sonified Urban Masterplan of Paris, allowing us to listen, either independently or in combination, to the spatio-temporal organization of the city. The effectiveness of the sonification is assessed in a public survey.

Then, we explore the use of the SUM tool in the analysis of everyday urban rhythms – towards a sonified Rhythmanalysis. We aim to represent the various everyday rhythms of Paris, from the point of view of its citizens. Thus we conduct a mapping survey in which participants were asked to map their space-time movements over a day. We recognize four types of everyday rhythms: regional; suburban; metropolitan; and inner-city. An example of each rhythmic type was sonified and their owners asked to identify their paths by ear. Through the use of sound we explore the temporal opportunities and constraints the city of Paris has to offer.

9 Sonified Urban Masterplan: Paris

In this chapter, we apply the SUM tool to our case-study city of Paris in order to generate a series of datasets composed of a map of the elements of each urban system. Each image dataset is then sonified using the SUM Urban Instruments previously developed, resulting in a Sonified Urban Masterplan of Paris. Each urban system can be listened to either independently or in combination. Played by a path or paths of interest, the composition along this path can be heard over time. As a comparative study, we sonify the urban design of several street types found in Paris. The differences in their spatio-temporal compositions can be heard. The effectiveness of our sonification of Paris is then assessed through public consultation.

9.1 Sonifying the rhythms of Paris

In this section we present our strategy for the sonification of each of the following urban systems of Paris and their urban parameters of interest.

1. **Natural Environment** – from the river Seine which feeds the city, to its open spaces, such as natural woods and man-made parks and gardens

2. **Transport Infrastructure** – including public infrastructure at regional and metropolitan rail, as well as the road network, its traffic flows, and cycle paths

3. **Urban Morphology** – consisting of the form – position, length and height – of buildings as well as their typology

4. **Activity Distribution** – consisting of the various types of public services provided by the city of Paris, including: Community; Entertainment; Education; Health; Office; Sport; Commerce; Public Open Space

5. **Urban Design Elements** – consisting of objects such as building structure, barriers, lights, bins, trees and monuments.

Each sonified urban map presented below is the result of an image dataset whose individual image data-sources can be found in *Appendix 3: SUM Urban Datasets.* The data used in the generation of these datasets is the most recent open data, provided online by their respective institutions.

9.1.1 Transport Infrastructure

Transport infrastructure in Paris includes its regional (RER) and metropolitan (Metro) rail, systems as well as its road network of vehicular traffic flows and cycle paths. Since we are concerned with infrastructure systems, the sonification of multiple paths is involved. Here, we sonify the RER regional railway system (Figure 9.2) using the SUMtransportplayer previously shown, according to the SUMscore in Figure 9.1.

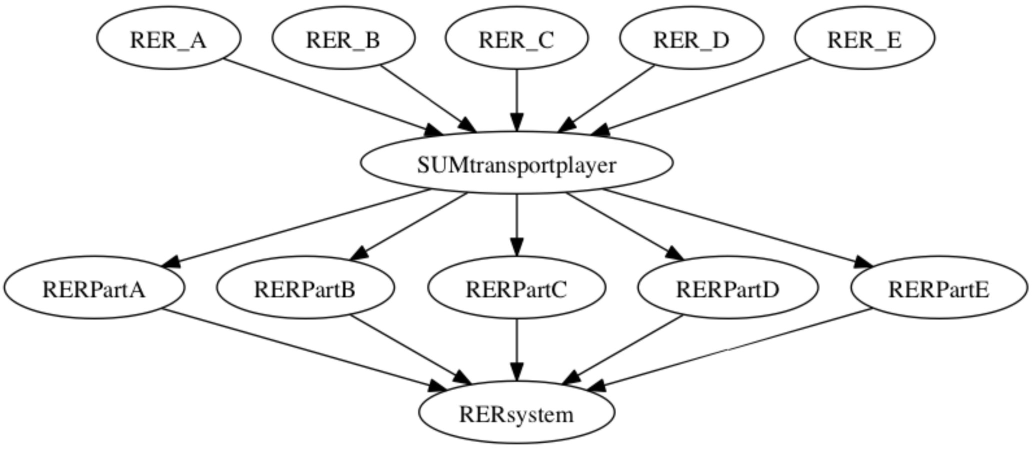

Figure 9.1: SUM score of RER transport system

Each RER line becomes a SUM part, shown colour-coded in the piano-roll seen below:
https://www.dropbox.com/s/zxqnawupbykcpi4/SUMtransport_RER%2Bgare_cut2.mp4

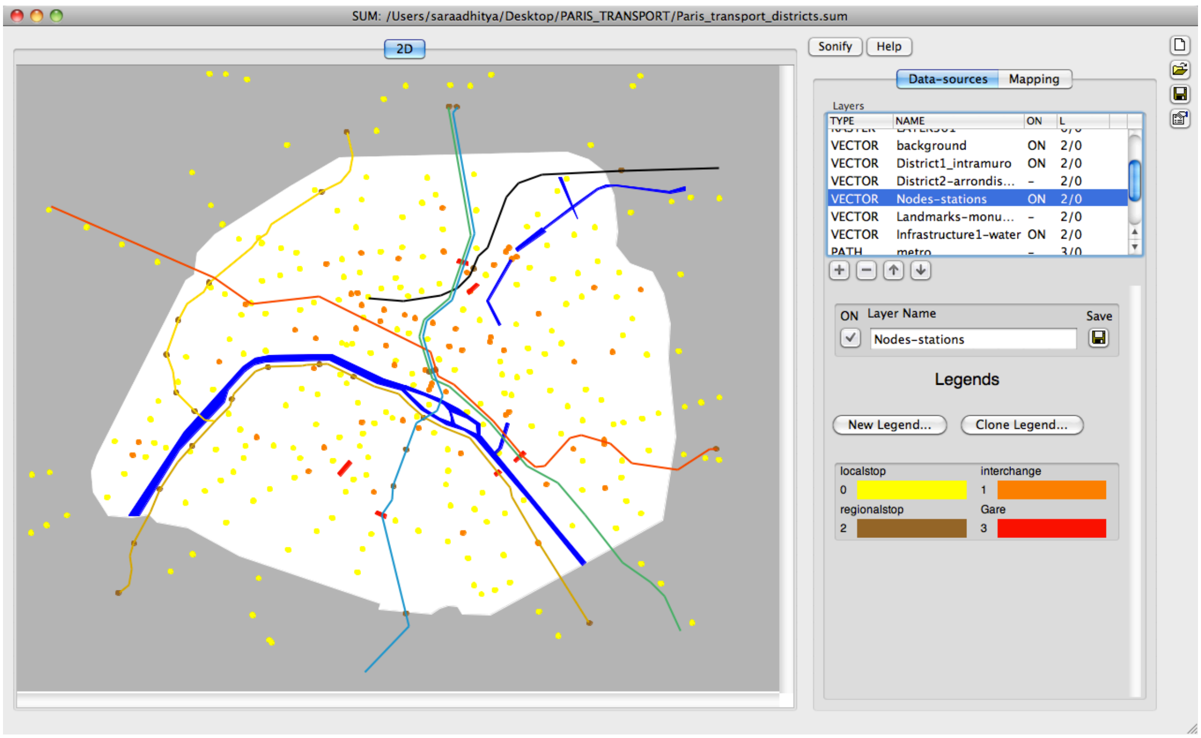

Figure 9.2: SUM Dataset - Regional railway network (RER)

9.1.2 Urban Morphology

Paris' urban morphology, also known as its urban fabric, consists of the overall distribution of its built form (shown in Figure 9.3). This is determined by the organisation of its streets, which in turn form blocks, and the building typologies themselves, which produce different rhythms according to their position, length and height.

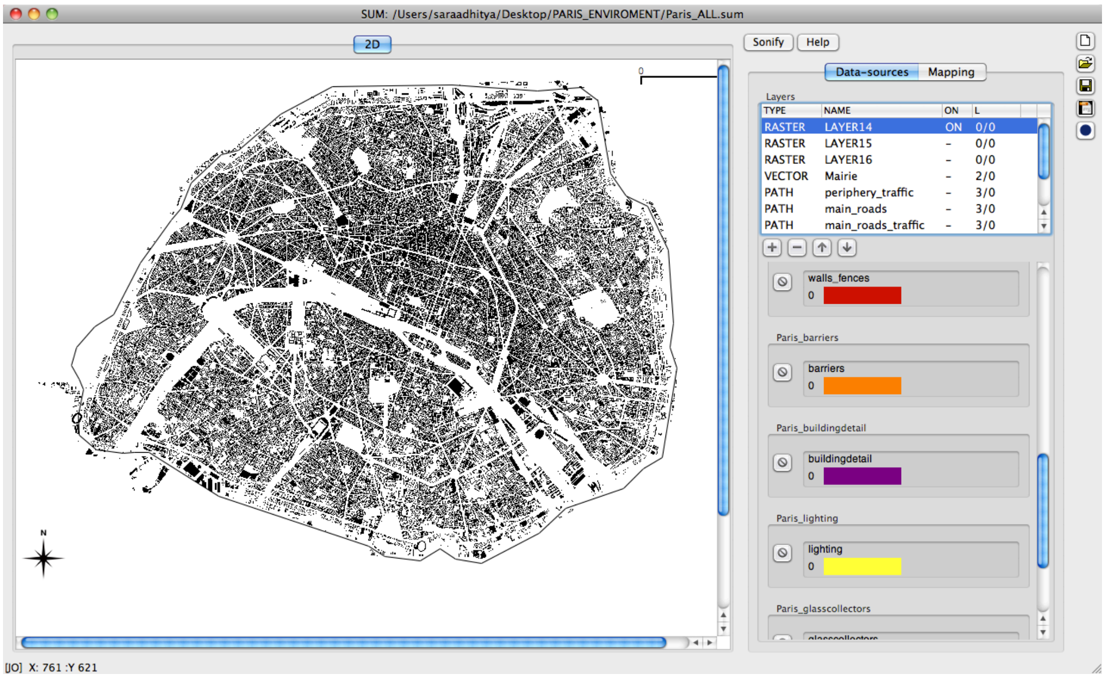

Figure 9.3: SUM Dataset – Paris Figureground

In Figure 9.4 we can see three different urban typologies found in and around Paris: Hausmannian; bars and towers; and the pavilion style found in the periphery. We can listen to the different rhythms created by these contrasting urban fabrics in the video below: https://www.dropbox.com/s/d8817wfzyv0oqls/UF_comparison.mp4

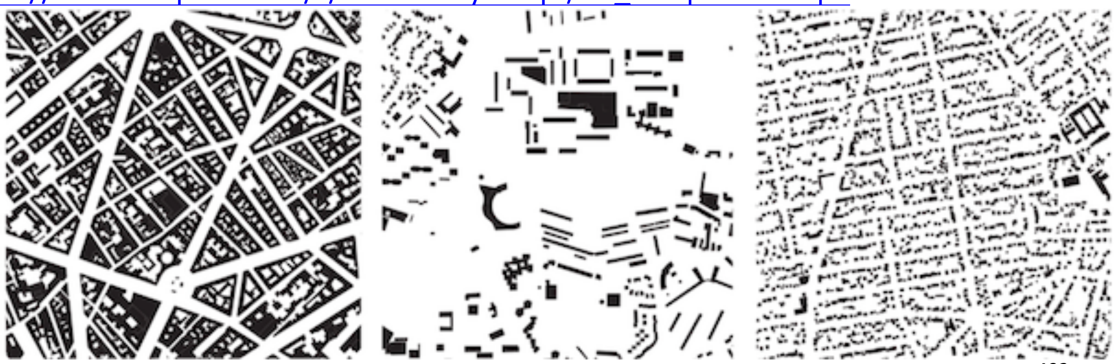
Figure 9.4: Comparison of different types of urban fabric in and around Paris[402]

The approximate height of the buildings have been mapped to pitch, with the 6-8 storey Hausmannian fabric much lower than the more dispersed fabric which, in order to accommodate the required inhabitable volume, must be high-rise. The lower density of the low pavilion style houses is heard in its lower pitch and more frequent rhythm.

[402] Rogers 2009 p.72

9.1.3 Activity Distribution

Public urban activities in Paris can be categorized as follows: Community; Entertainment; Education; Health; Office; Sport; Commerce. These activities are normally presented as separate maps, as can be seen in *Appendix: SUM Urban Datasets*. Overlaid, these elements can be difficult to read, as seen in Figure 9.6, in addition to requiring frequent references to the legend. Sonification by the SUM tool allows superimposed elements to be heard at the same time as well as intuitively understood through iconic representation. The SUM score for listening to the distribution of urban activities can be represented as in Figure 9.5.

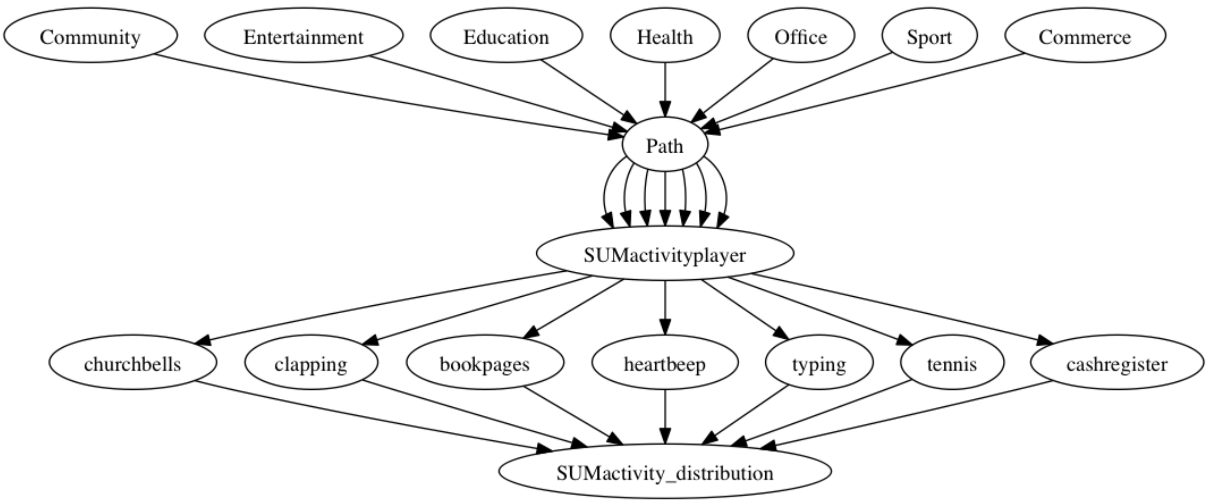

Figure 9.5: SUM score for the sonification of activities along a given path, representing in order (from top to bottom): data-source, path, mapping instrument, SUM part, sonification.

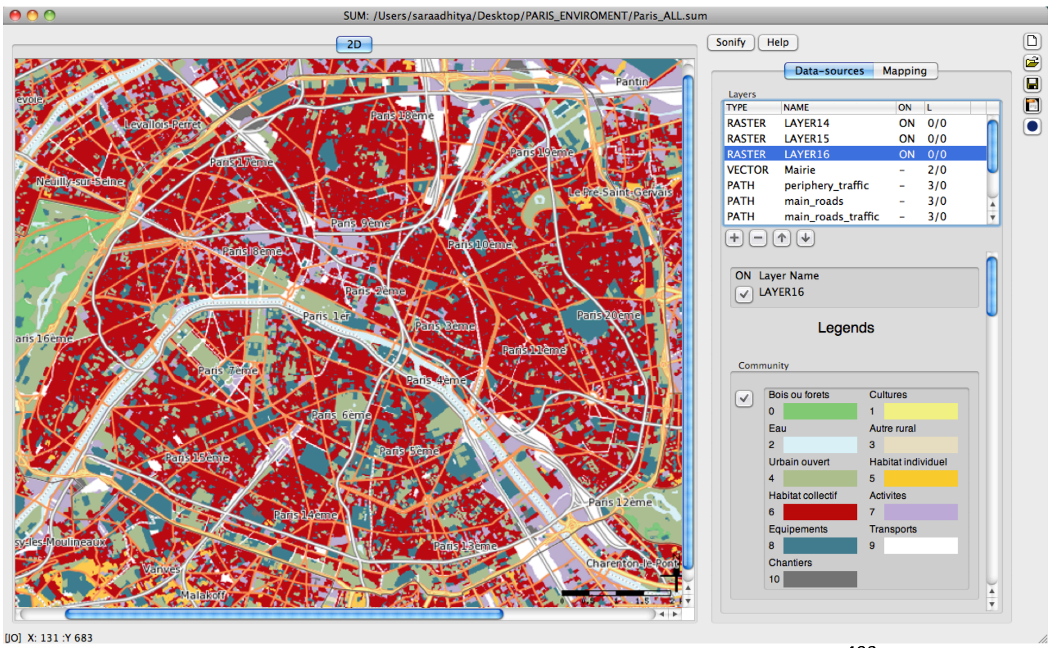

Figure 9.6: SUM dataset: Overlay of urban activities[403]

[403] Data Maps used in SUM obtained from Institut d'Aménagement et d'Urbanisme, Ile de France, *Visau (Carte Interactive)*, http://www.iau-idf.fr/cartes/cartes-et-fiches-interactives.html [Accessed February 2012]

9.1.4 Urban Design Elements

Urban design elements - including building structure, barriers, lights, bins, trees and monuments - are usually smaller-scaled but nonetheless have a major impact on the composition of local urban experience. The individual distribution of each element can be graphically seen in *Appendix 3: SUM Urban Datasets*.

Due to the small size of these local elements, visualization is a problem, especially at the city scale (Figure 9.8). However, a coherent urban design strategy should be addressed at this scale. The SUM tool allows us to play these elements simultaneously at any given speed, regardless of the graphic scale. The SUM score for playing these urban design elements can be represented as in Figure 9.7.

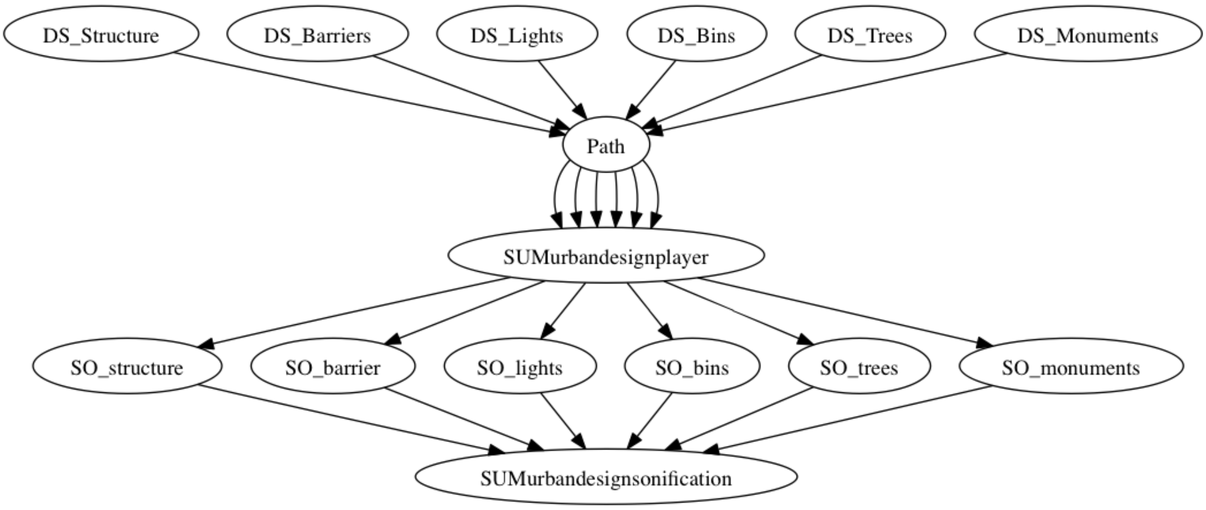

Figure 9.7: SUM score: Urban design sonification (DS = data-source, SO = sounding object)

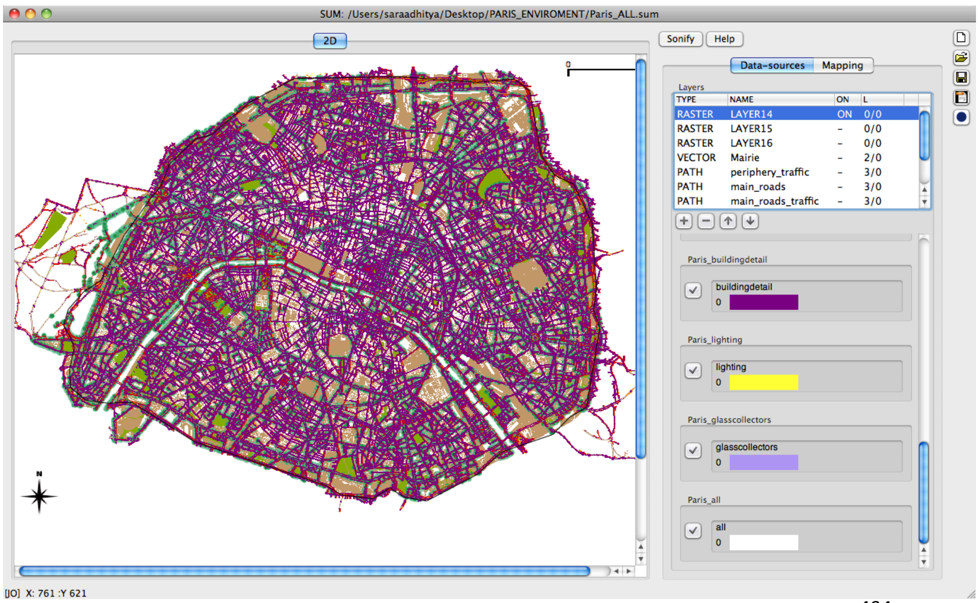

Figure 9.8: SUM dataset: Overlay of urban design elements [404]

[404] Maps based on data obtained from Marie de Paris, *Paris Data*, http://opendata.paris.fr/opendata/jsp/site/Portal.jsp?page_id=5 [Accessed February 2012]

9.2 Sonifying SUM streets of Paris

We will now sonify this Urban Design dataset along three main types of streets found in Paris, in order to compare the organization of their urban design elements:

IV. Boulevards
V. Avenues
VI. Streets

Each of these street types are designed to support different transport flows. The sonification allows their resulting composition to be heard at their respective speeds of movement.

9.2.1 Boulevard

A boulevard is normally used to refer to a wide, arterial thoroughfare for regional traffic, often with slower lanes for local traffic along the sides, where it is usually lined with trees.

While of a somewhat smaller scale, Boulevard de Sébastopol is nevertheless an important part of Haussman's strategy in the 1850's, intended as a major north-south transport corridor through central Paris. It runs 1.3km north from Place du Chatelet on the right bank of the Seine. In the traditional French style, it is tree-lined on both sides. It consists of 4 lanes of traffic, including a bus-lane which can also be used as a cycle path. In Figure 9.9, we have chosen to travel along the boulevard by bike.
(Demo video: https://www.dropbox.com/s/kq01d4j4ic4qr4d/UD_CP_bvdSP.mp4)

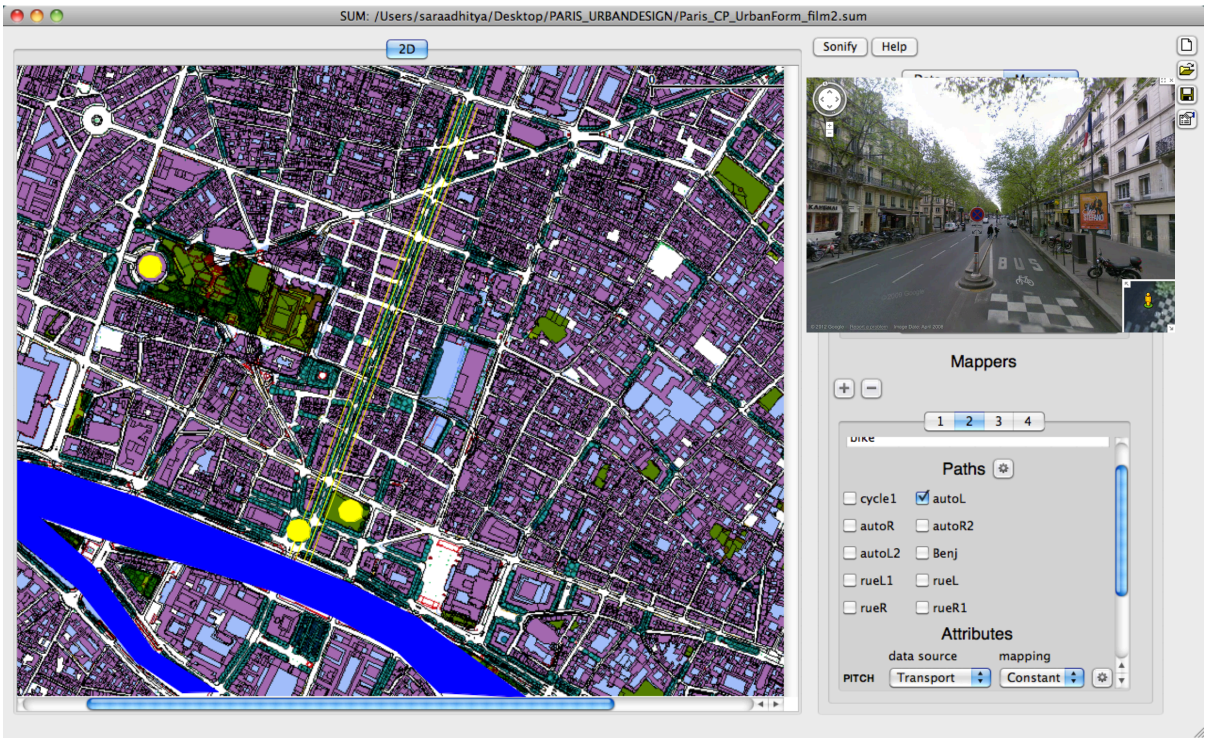

Figure 9.9: Sonification of Boulevard de Sébastopol, Chatelet

9.2.2 Avenue

An avenue is a medium to high capacity arterial road usually heavily landscaped. The Avenue des Champs-Élysées runs 1.91km from Place de la Concorde (east) to Place Charles de Gaulle (west). It is lined on both sides with thick bosquet planting, and connects two famous monuments: the Obelisk and the Arc du Triomphe. This extremely wide thoroughway is best suited to vehicular travel and we play the following sonification shown in Figure 9.10 at the speed of a car. This produced a shorter sonification due to the faster travel speed.
(Demo video: https://www.dropbox.com/s/6yhkmy9no8p9a28/UD_AT_aveCE.mp4)

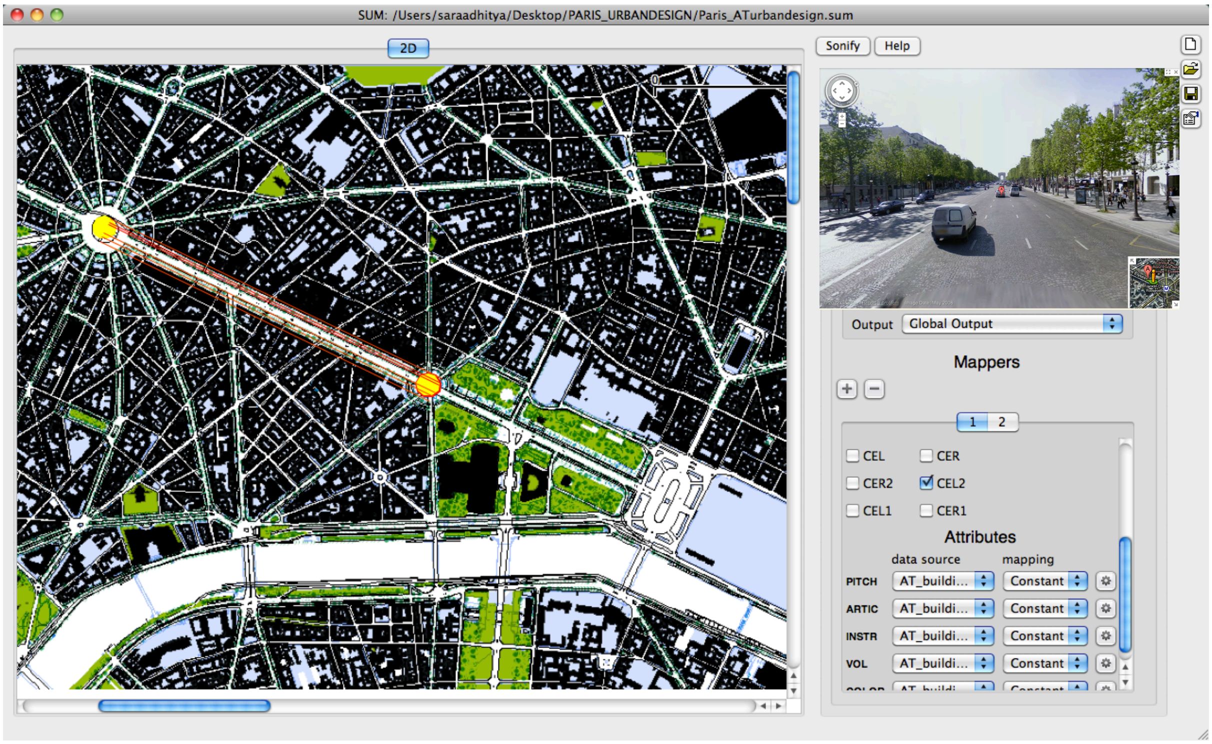

Figure 9.10: Sonification of Avenue des Champs Elysées

9.2.3 Street

For many years, the smaller streets of Paris were treeless. However today with the city's greening strategy, this is now often not the case. Rue Saint-Martin is one such example. Lying parallel to Boulevard de Sebastopol, as shown in Figure 9.11, it was in fact first destined by Haussmann to be the major N-S axis. Originally 7.2m wide, the plan to expand it to 22m in 1851 was rejected. Today it seems relatively narrow, and for some parts is zoned as pedestrian only. Here we sonify the pedestrian section at the southern end of this street, as experienced on foot.
(Demo video: https://www.dropbox.com/s/86v2zjd04ahmpe5/UD_CP_rueSA.mp4)

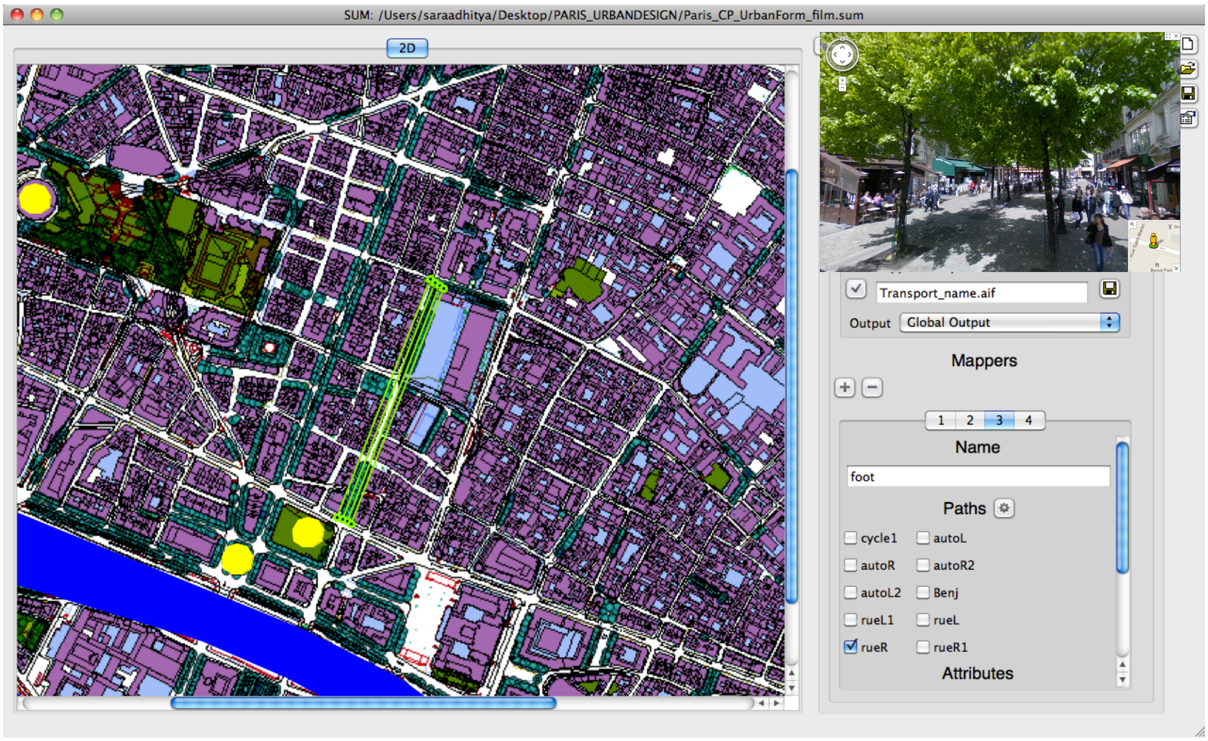

Figure 9.11: Sonification of Rue Saint Martin, pedestrian section from Place du Chatelet

Discussion: Listening to the streets of Paris

From these three sonifications of different street-types in Paris, we can hear the rhythmic differences in their urban design at their respective speeds of travel. In the future we hope to compare the same path with different modes of transport, and the same mode of transport on different paths, in order to allow comparative listening.

Similar comparisons can be done for each urban system of activity, transport, form and environment. All can be combined according to the SUM score in Figure 9.12, in order to listen to the overall rhythmic composition of the street.

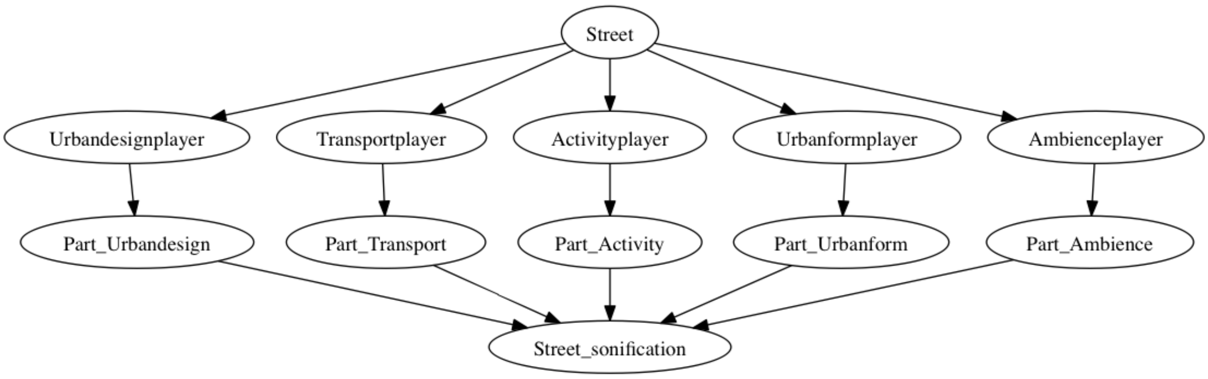

Figure 9.12: SUM score for the synthesis of all urban systems along a given street

We apply this in its entirety to Boulevard de Sebastopol in order to hear its overall urban composition. The results are presented in a video in the following section, followed by an assessment of this sonification by the general public.

9.3 Listening to SUM: Paris

In this section, we assess the effectiveness of the SUM tool and our urban sonic code as applied to Paris. A questionnaire was conducted in which 25 members of the general public was asked to reflect on their experience of the Sonified Urban Masterplan of Paris. They consisted of a variety of ages, nationalities, disciplines, and musical skills. The only criteria was to not be an urban professional, in order to determine how much urban information was gained through the use of sound. Participants were presented with the following online video entitled 'Sonifying Urban Rhythm':

https://www.dropbox.com/s/wem2p02atb0l4g9/SUM_VIDEO_send.mp4

Figure 9.13: Presentation video of the Sonified Urban Masterplan of Paris

They were then asked to respond to an online survey, which can be found in further detail in *Appendix 4: Questionnaires & Experiments (Questionnaire 1).* Their responses are discussed below.

9.3.1 Initial responses

'I found it to be very interesting, both artistically and from a more practical point of view. The sonified elements really complement the image by intuitively providing an overall feel of the area while also being an interestingly pleasing musical experience.'[405]

The Sonified Urban Masterplan of Paris attracted a variety of responses from a non-specialist audience. These responses can be categorized as emotional, aesthetic and intellectual and will be described accordingly below.

Emotional response

The emotional responses that SUM provoked in viewers ranged from initial *'surprise'* and *'intrigue'*, to *'happiness' and 'friendliness'.* Depending on the type of street, people reported feelings of monotony when *'walking in common streets'*, intensity and anxiety in areas of greater density, and satisfaction when '*arriving at streets with parks, water and markets*'.[406]

Feelings of recognition were also acknowledged by those who were familiar with represented areas. SUM was reported to have 'transported' them to the place represented, allowing them to 'relive' their experiences with greater awareness: *'It's a much deeper experience than just looking at a map. As the examples in the video are about places I've been to, I feel transported there and biking down Boulevard de Sebastopol but in a more aware fashion than I would normally do.'*[407] This suggests the ability of sound to embody memory, attributed mostly to the use of iconic sounds: *'emotional: -I lived in the area for 6 years and the analysis of Bld Sebastopol feels very familiar - many of the sounds evoke emotional feelings as they mimic the real sound'.*[408]

Other participants who were not familiar with the city or the mode of transport, claimed that the sonified representation of Paris helped them imagine what it would be like to be there: '*Looking at the map and listening to the music simultaneously provoked visualisation of the journey.'*[409] Overall, SUM was recognized as a tool *'capable of triggering powerful emotions'.*[410]

Aesthetic response

Aesthetically, SUM: Paris attracted a wide range of responses, generally positive including pleasant, beautiful, charming, and calm. Its role as a means of communication of urban data was acknowledged, with the resulting sonification described as a '*…natural and almost playful data representation.'*[411] However, the sonification was also appreciated as a '*new*

[405] Appendix Questionnaire 1, Q1, Subject i
[406] Subject xviii.
[407] Subject vii.
[408] Subject xvii.
[409] Subject iv.
[410] Subject xxi.
[411] Subject xx.

way to compose music.'[412] Several participants referring to the resulting sonification as a *'musical composition'* and described their experience of SUM as *'like listening to a piece of music'*. [413]

Intellectual appeal

For those who did not respond emotionally to the sonification, SUM demonstrated its intellectual appeal in what was described as an *'interesting approach to display and interpret urban design and use'.*[414] The non-architect/urbanist audience reported a number of new aspects that they learnt about the city from their experience of SUM, including the impact of one's environment, the variety of different urban systems, and the composition of the city: '*New and repeated sounds drew my attention to the variety and placing of different aspects of the city, and made me realise that these might be more intentional and "beautifully" placed than I had first realised!'*[415]

SUM also evoked interest, curiosity and the desire to learn more: *'makes me curious what will come next while exploring a city'.*[416] There was a curiosity to use the tool to interpret more paths and compare cities with the same sonic code.[417] SUM also succeeded in igniting the desire to *'…enjoy more the sounds all around the places that I visit'*.[418]

9.3.2 Effectiveness of sonification

The effectiveness of the acoustic communication of urban data ranged from listener to listener. There was a general acceptance and understanding concerning the iconic sounds. However, the more abstract sounds received mixed reactions: '*Overall the representational samples were easy to identify, but the synthetic sounds less so.'*[419]

There was a range in the receptiveness of participants to the abstract mapping, with some participants more receptive to the abstract mapping than others. This can be attributed to the lack of prior explanation of the urban sonic code, to be expected from an initial viewing. However, any confusion can be appeased in the future by prior learning of the code. As recognized by one subject: *'Of course, some mappings are easier to interpret with no training, while for others I would need some more experience*'.[420]

Most participants responded well to the connection between the sound and graphics – or

[412] Subject ix.
[413] Subject i.
[414] Subject ii.
[415] Subject xxii.
[416] Subject xxiv.
[417] Subject xiii.
[418] Subject xxi.
[419] Subject xiv.
[420] Subject xviii.

the formation of audio-visual objects - as represented by the moving cursor: *'One can easily assimilate the visual data presented as (s)he follows the structured relationships between them!'*[421]

9.3.3 SUM Communication

Participants identified a number of 'dimensions' of the city revealed by SUM that are not normally shown in a graphic plan, including the plurality of the city, the expression of movement and experience, and human activity and urban life in general.

Plurality

'SUM reveals the extraordinary plurality of the city. When walking through a city, either we are unaware of its various aspects, either we observe them one to one. When we look at a simple plan, it is flat, uniform, and does not reveal the plurality. With the sonic polyphony of SUM, we see immediately that plurality.'[422]

SUM was recognized for its ability to reveal the plurality and diversity of the city due to the polyphonic nature of sound: *'While visually you can only focus on one thing, aurally you can have more than one input.'*[423] On the other hand, the graphical plan was recognized as limited to the representation of single urban aspects, in order to avoid becoming '*very noisy and impossible to communicate with*'.[424]

Participants also reported that SUM's use of acoustic semantics aided the 'reading' of a map by avoiding the 'looking-up' of a colour legend normally required by the graphic plan: '*Assuming that all the information layers that are used in SUM were displayed on a graphic map, it would be very dense and require frequent references to the legend.'*[425]

Thus SUM was able to represent aspects of the city not normally representable in a graphic map: '*It is really impressive to realise how many different things are going on at the same time.'*[426] It was also reported to represent '*the small details of a city*'[427] that a simple graphic cannot. Thanks to this sonic dimension, SUM was described as more 'informative' and 'enriching'.

Movement and Experience

'It was more experiential than just looking at a graphical plan, gave me a sense of

[421] Subject xx.
[422] Subject viii.
[423] Subject x.
[424] Subject xvii.
[425] Subject vii.
[426] Subject x.
[427] Subject ix.

timing of a place in a similar way to physical travel.'[428]

SUM also was acknowledged for its dynamic qualities and its ability to represent movement in the city. Qualities of temporal experience, such as changes in spatial density, repetition, and variation, were reported. Bikers reported recognition of the rhythms represented in the biking sonification. The path speed was reported to help with the understanding of distances, as well the necessary travel time: '*The pre-set pace also allows me to have an idea of distances. With a purely graphic map it is often hard to judge how long it would actually take me to walk or bike from one place to another - especially for an unfamiliar city.'*[429]

People and 'Life'

Last but not least, SUM was described as giving 'life' to the city by representing how it is used by its' inhabitants. The temporality of sound allowed the representation of transitions from place to place, as well as the processes of 'interaction and evolution'. SUM was attributed for its ability to represent that *'The fact that the city is alive, that there are things that happen and change, that walking in a street you can see many different things from one square to the other and discover things.'*[430] The more iconic sounds were reported to increase subjects' awareness of the different types of activities in different areas. Thus SUM's potential to 'reveal the connections between the urban and social systems' was also identified.

9.3.4 SUM Rhythmic awareness

'In essence, it could increase the awareness of my own rhythm of life.'[431]

SUM was reported to increase the awareness of rhythms in the city at a number of different levels. For some it was an introduction to urban composition never before considered: *'Rhythms of urban design and morphology were kind of surprise for me. The overall feel of the city may now be decomposed as well!'*[432]

For those who claimed to be already 'rhythmically-aware' of the sonified city and neighbourhood, SUM was identified as more useful in representing the unknown: '… *I believe that it can definitely reveal things about an unknown place or a given moment in the city.'*[433]

Two types of rhythms were identified: *'the inherent rhythm of ambient sound in noisy places like markets and schools, and then the slower rhythm of changes as you travel through*

[428] Subject xxii.
[429] Subject vii.
[430] Subject xviii.
[431] Subject xiii.
[432] Subject xx.
[433] Subject xviii.

different areas.'[434] This was in line with the two types of urban rhythms identified in Part 2 – the rhythms of place and the rhythms of path.

SUM can also be seen to have succeeded in increasing the awareness of urban rhythms of the participants, which was often admitted as something previously ignored: *'… I'm not even aware of it while I'm walking in the city itself. I'll go through crowded places and more silent areas but will not perceive the inherent rhythm consciously.'* [435]

Responses also indicated the ability of sonification to represent embodied rhythmic experience. A biker was able to recognize the rhythms experienced on the road: *'As a biker I did have some awareness that fitted well to the rhythms represented…'.*[436] Realising that the perception of rhythms changes with the speed of movement, there was a repeated desire to listen to more sonifications using different modes of transportation at different speeds.

This ability to explicitly represent rhythm was attributed to its use of iconic sounds, its acceleration of time and the resulting '*condensation of repeating structures in a more easily perceivable timescale'*.[437]

9.3.5 SUM Contributions

'It represented an experience of the city in a different way, and listening to the music helped me to not take things for granted that I normally would.'[438]

As discussed above, SUM introduced a new approach to everyday life that many participants had not previously acknowledged - understanding the city through its rhythms. However, the incorporation of sound showed its potential to contribute to urban understanding in a number of other ways, from the awareness of the urban soundscape, urban decision-making, and the enhancement of the urban experience.

Soundscape Studies

'The use of soundscape as a different way of rediscovering a known city, or of discovering an unknown city.'[439]

Through its use of sound, SUM introduced the concept of soundscape and of listening to one's environment to those not previously aware: *'I was surprised by the number of sounds that one can find in a city and how each small structure and activity has a sound.'*[440] Subjects responded positively to the approach SUM presented of 'listening' to one's city, which they

[434] Subject xiv.
[435] Subject xiv.
[436] Subject iii.
[437] Subject xxv.
[438] Subject xxii.
[439] Subject xiv.
[440] Subject ix.

would be able to apply in the future: *'I will be more careful to the sounds I hear when I'm in the street'.*[441] This suggests SUM's future potential in the 'ear-cleaning' process of R.M.Schafer.

Decision-making

SUM was recognized for its ability to sonically represent the qualities of different neighbourhoods: '*...with SUM you are better informed about what you can find in a neighbourhood, and what "types" of neighbourhoods there are around the city...'.*[442] There was an interest in discovering the sound of neighbourhoods with different qualities, such as 'ugly' or 'dangerous'. This led participants to pose the question: *'Could I be able to learn with SUM whether I would like an area?'* [443]

Thus SUM was proposed as a tool to help make choices of where to live according to pre-defined interests. It could be used to understand the level of activity in an area, allowing one to choose either the '*hustle - bustle or the calm'*.[444] This capability was recognized as particularly useful for real-estate agents to communicate the characteristics of particular neighbourhoods and for future-tenants to decide where to live when looking for a new apartment.

SUM was also recognized for its potential to help in decision-making on a more daily basis. Users would be able to choose a particular route for its rhythm composition, such as '*whether I choose to take the metro or bike, or whether I choose a boulevard for rapidity or a detour in a park'.*[445] At the same time it could be used to choose routes for its sonic qualities: *'how I could choose to travel via a route that is audibly pleasing.'*[446]

Urban Experience

SUM's ability to enhance the urban experience of the sight-impaired was identified. It could also provide an experience of moving through a city 'without actually being there'. SUM could be used to reveal certain urban aspects of interest. For example, it could highlight to inhabitants or tourists certain desirable aspects of a city, such as parks, monuments, community or historical importance. Thus it could serve as a reminder or means of valorisation of the elements of the city that often go unseen or forgotten.

Last but not least, its possible utilization in future related research was also proposed, such as the effect of urban structure and its soundscape on the psychology of its inhabitants.

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[441] Subject xxiii.
[442] Subject x.
[443] Subject vii.
[444] Subject ii.
[445] Subject ix.
[446] Subject ii.

9.3.6 Potential use of SUM

A number of suggestions were made regarding how SUM could further enhance one's experience of the city in the future, including the sonification of other urban rhythms, their comparison over time and space, and the development of interactive applications.

Application to other rhythms

Participants suggested a number of urban rhythms which they would be interested in sonifying using the SUM tool, including activity levels, traffic jams, the weather and crime rates, as well as the overall sound level itself.

A comparative tool

Many subjects indicated a desire to compare the rhythms of different neighbourhoods or cities, and observing how the rhythms change over time. These rhythms could be compared at different times of day, from morning to night, or on different days of the week or from summer to winter.

Interactive Applications

A number of participants expressed the desire to '*play with it myself*', in order to test out different routes or areas of personal interest. While SUM already allows many of the features they requested - including the ability to select sounds, elements and areas of interest, as well as traverse the map at different speeds and scales - a more interactive interface was proposed. One participant suggested *'a touch panel approach where you look at the city, zoom in with your hands and where you then touch you get the SUM of that area.'* [447]

The integration of SUM with other available technologies also produced some interesting future applications. Combined with mobile technology, SUM could become a '*giant audio guide*'. Used in the metro and trains, SUM could enhance passengers' urban awareness by being able to hear the urban rhythms above ground. In combination with interactive feedback from other users, the most popular routes could be better understood. This could help consumers to locate certain activities or businesses, and business owners to advertise.

[447] Subject xvii.

Discussion: The use of SUM in urban representation

'Listening to the transposition in sound of the monuments, offices, markets, trees of Boulevard Sebastopol opened me up to the possibility that this manner of interpreting the urban dimension may in fact help to develop a deeper understanding of the city in which I live.'[448]

The initial response to the Sonified Urban Masterplan of Paris demonstrates the potential of SUM as an urban representation tool. The variety of responses it evoked – emotional, aesthetic and intellectual – demonstrates the power of sound to communicate on a number of levels. Subjects confirmed the ability of sonification to represent urban movement, experience, rhythm and 'life' in general. Furthermore, many took away with them a new approach to understanding the city through listening, both to the soundscape and to their bodily experiences. The sonic dimension also helped communicate the plurality of the city often lost in the graphic plan, allowing one to understand the relationship between different urban systems, as well as their place in the 'rhythmic web' in which they live and move. Further training in the sonic code would allow the advancement of sonification as a technique of urban representation. Last but not least, the variety of suggestions for applications of SUM in the future indicates a desire to learn more about one's city as well as to interact with it.

[448] Subject xiii.

10 A Sonified Urban Rhythmanalysis

In this chapter we apply the Sonified Urban Masterplan tool to the sonification of different everyday live-work rhythms found in Paris. This allows us to identify the various commuting rhythms the urban infrastructure of Paris supports. In particular, we focus on the opportunities and constraints offered by its public transport infrastructure on one's daily activities. Through this exercise, we establish a methodology for a 'Sonified Urban Rhythmanalysis', which may then be applied to other urban issues in the future.

10.1 Daily Urban Rhythms in Paris

The first part of the Rhythmanalysis was established through a survey in which various subjects living and/or working in Paris were asked to draw the path of their typical weekday movements (as shown in Figure 10.1). They were asked to indicate all major activity destinations (home, work, shop, bar, theatre etc.) and their chosen route, including the mode of transport (bus, foot, metro, RER etc.). They were also asked to specify the time (e.g. 9:00, 21:00), which allowed us to understand their activity distribution over time.

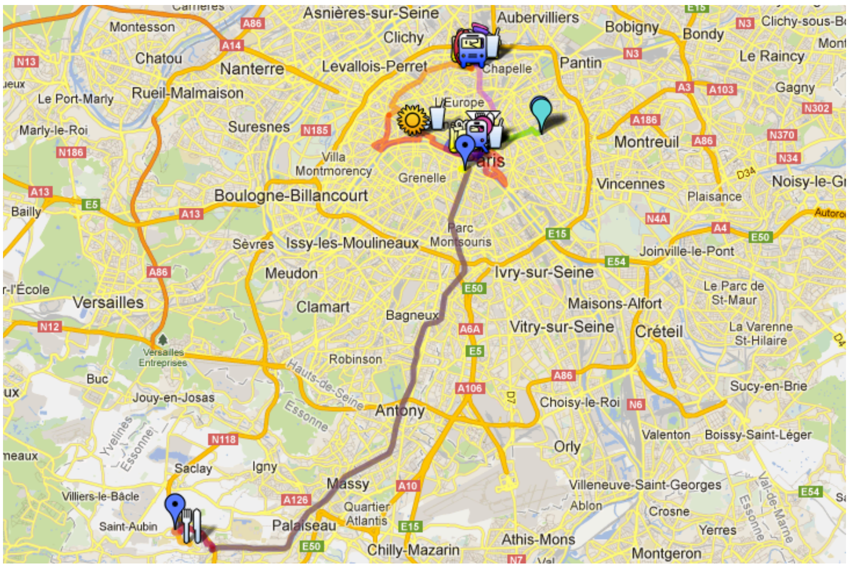

Figure 10.1: Mapping of daily space-time-use paths in Google maps

Four main types of daily rhythms were identified, according to the living and working habits of the subjects:

1. Regional
2. Peripheral
3. Metropolitan
4. Inner-city

We will focus on the daily experiences of 8 of the initial subjects, who were representative of these 4 main rhythm types. Their sonifications are provided in the links below.

10.1.1 Regional rhythms

Subjects 1 and 2 (Figures 10.2 and 10.3) have very similar daily rhythms. They both work outside of Paris in Orsay but choose to live in Paris for life-style reasons, mainly to benefit from the social and cultural amenities for the city. The only public transport service is the regional train RER B and connecting bus. However, they expressed their dissatisfaction with this service due to the length of time to complete this journey - up to 1.5 hours with an estimated delay of 30 minutes at least once a week. Both subjects lived near train stations along the RER B train line in order to limit their commuting time. However, with 2.5 – 3 hours travel time a day, their actual time spent in Paris was restricted, contrary to their initial aim of enjoying what the city centre has to offer.

(Sonification 1, 2: https://www.dropbox.com/s/hbwktkm092i5x9v/SUMpathsB_S1.avi)

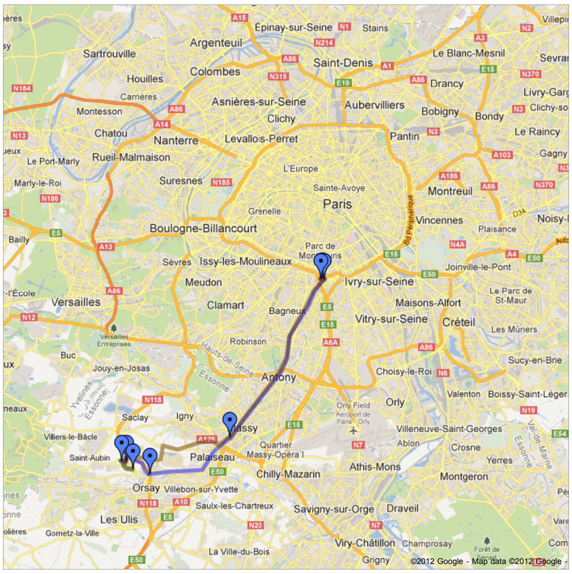

Figure 10.2: Subject 1

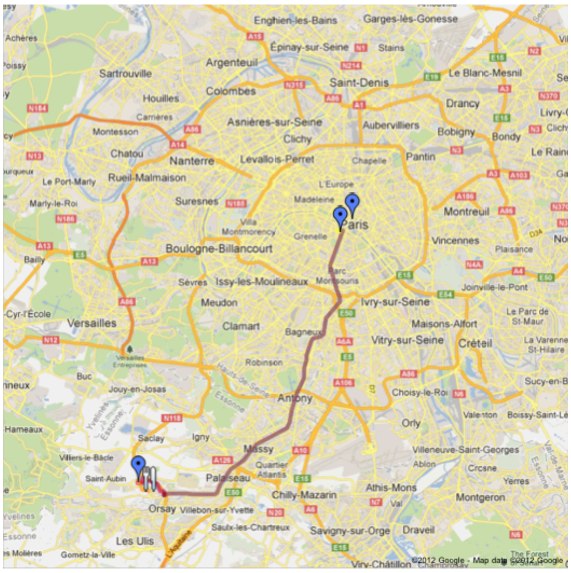

Figure 10.3: Subject 2

10.1.2 Peripheral rhythms

Both Subjects 3 and 4 live in the same location in the north-east periphery of Paris, yet have very different daily rhythms due to their work, as can be heard.

Subject 3 (Figure 10.4) works in the periphery but on the other side of Paris. Unfortunately, due to the centralization of the regional transport system, he is obliged to pass through Paris in order to get from home to work. This requires three changes of transport, from metro, to RER to bus, which signifies for Subject 3 approximately 3 hours of commuting per day.

Subject 4 (Figure 10.5), however, work in various areas in the centre as a freelance teacher. Although she would like to move closer to the city centre, she is still able to access most areas quite easily with the metro.

(Sonification 3*:* https://www.dropbox.com/s/tmcr3c0ak041uhs/SUMpathsC_S3.avi)
(Sonification 4*:* https://www.dropbox.com/s/ygacsby52ptfpoy/SUMpathsB_S4.avi)

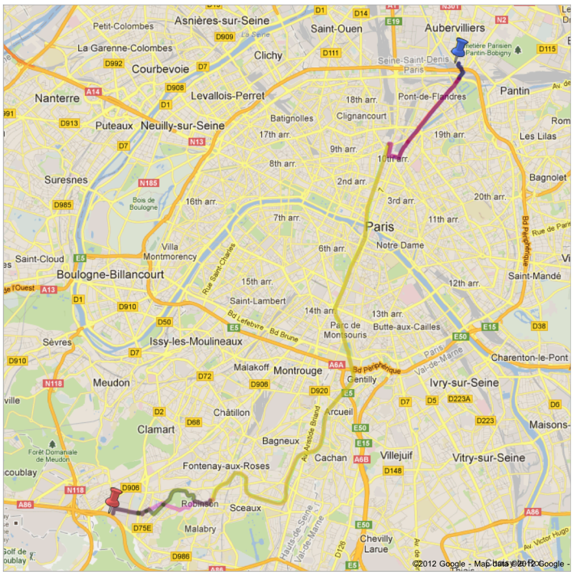

Figure 10.4: Subject 3

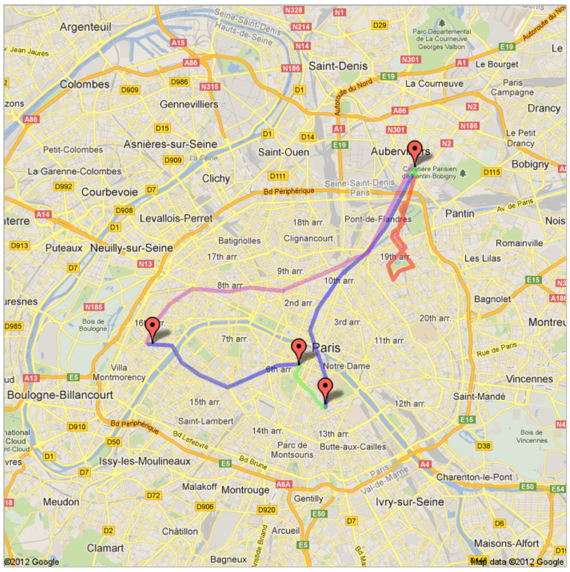

Figure 10.5: Subject 4

10.1.3 Metropolitan rhythms

Subjects 5 and 6 (Figure 10.6 and 10.7 respectively) both live and work within the walls of Paris. They have a number of modes of transport at their disposal, including the metro, bus and cycling. This allowed them to easily access most parts of the city and take advantage of it throughout the day and night.

Similarly to Subject 4, Subject 5 also does not have a regular, fixed destination. However, her location and public transport services enables her to navigate between these multiple destinations relatively easily.

(Sonfiication 5: https://www.dropbox.com/s/tetxzsgu0j0j8bt/SUMpathsA_S5.avi)
(Sonfiication 6: https://www.dropbox.com/s/xqzeg182t1f650p/SUMpathsA_S6.avi)

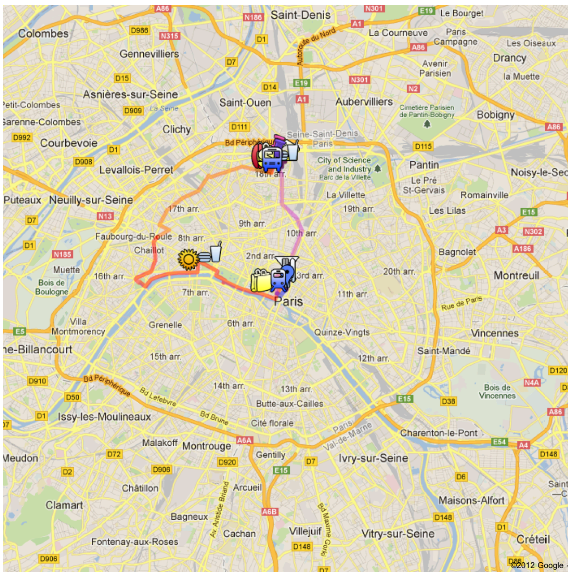

Figure 10.6: Subject 5

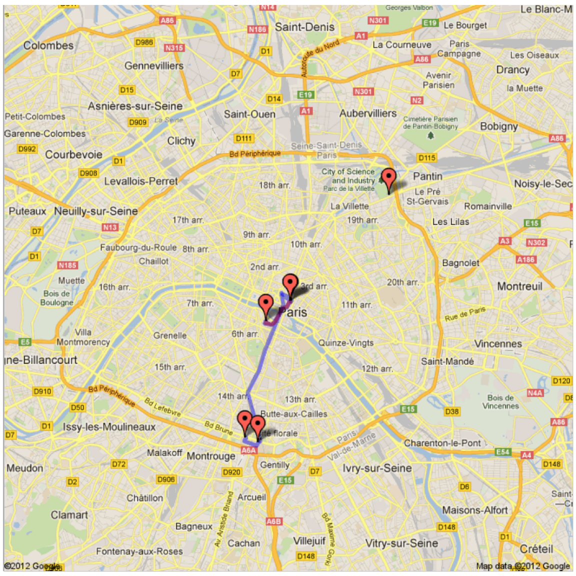

Figure 10.7: Subject 6

10.1.4 Inner-city rhythms

Subject 7 (Figure 10.8) and Subject 8 (Figure 10.9) both live and work in the centre of the city. They are able to cycle or walk to work, and easily access to most areas of the city throughout the day and night. They also can enjoy the commute, without dependence on public transportation. Subject 8 also has the convenience of living close enough by foot to make multiple trips between home and work during the day, which allows him to return home for lunch, a siesta, dropping of bags etc.

(Sonification 7: https://www.dropbox.com/s/14t6sxch3bcdr7v/SUMpathsC_S7.avi)
(Sonification 8: https://www.dropbox.com/s/ffz3kzpsqkuk08n/SUMpathsB_S8.avi)

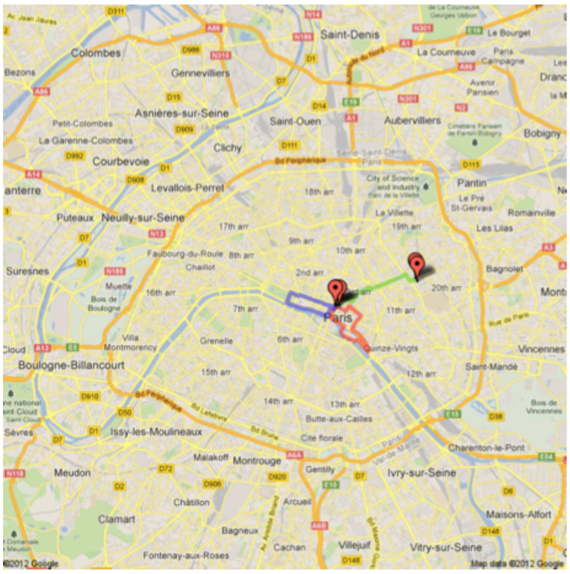

Figure 10.8: Subject 7

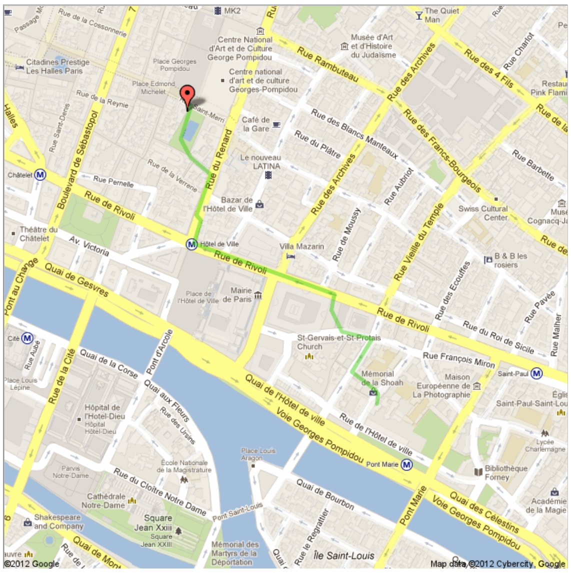

Figure 10.9: Subject 8

10.1.5 Inter-regional rhythms

Finally, a fifth rhythm was observed – the inter-regional rhythm. Subject 9 lives in Besancon due to the family home, while having to work in Paris on assignment 2 days per week. The commute is 3 hours by TGV. Fortunately the service is efficient and well-serviced, and he is able to work on the train. However, the distance is too long to be sustainable on a daily basis, and Subject 9 rents a room in Paris for the night, before returning home the next day. With increasing transport infrastructure, this rhythm is becoming surprising more common. However, not being of a daily frequency, we will exclude it from this study.

(Sonification 9: https://www.dropbox.com/s/evdn8n1t960j650/SUMpaths_JJ.avi)

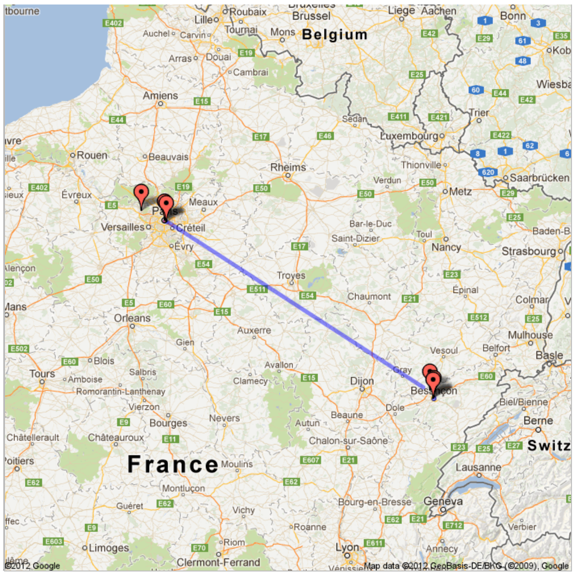

Figure 10.10: Subject 9

10.2 Sonified Daily Urban Rhythms

After obtaining the daily urban movements of the selected 8 participants, we then developed a methodology for sonifying their respective rhythms. Only the major events of one's day (i.e. primary transport means and activities) were taken into account.

First, we established the Urban Sonic Code, which was divided into three groups of sounds: transport; activity; and ambient. This code was explained to the participants in a short video, in which each sound was played for 3-5 seconds.
(video: https://www.dropbox.com/s/3y1w0z65kaznexi/SUM_survey_UrbanSonicCode.mp4)

Then, a brief Listening Exercise was conducted, involving the identification of sounds played. This was used to aid the learning of the sounds as well as to test the comprehension of the code. After one playing of the Urban Sonic Code (in which each sound was repeated twice), all participants identified at least 5 out of 6 sounds correctly. See *Appendix: Questionnaires & Experiments (Listening Exercise 1)* for further details concerning the experiment.
(video: https://www.dropbox.com/s/02ztbk6fetpf8f8/SUM_survey_ListeningExercise1.mp4)

Finally, each participant's daily rhythm was sonified according to the Urban Sonic Code, with their day proportionally reduced in time. Thus one hour was represented as 4 seconds (i.e. 15 min/sec), rendering a normal day less than 1 minute in duration. After listening to their personal Sonified Daily Urban (SDU) rhythm, without the visual aid of their map, the participants were then asked to respond to several questions regarding their experience of listening to their SDU rhythms.

See *Appendix 4: Questionnaires & Experiments (Questionnaire 2A)* for further details concerning the experiment and the participants' individual comments.

10.2.1 Effectiveness of representation

'You start feeling your daily work-live rhythm, instead of planning it.'[449]

The reactions of the participants to their Sonified Daily Urban (SDU) rhythms depended largely on the individual rhythms themselves. Aesthetic responses varied from '*monotonous and boring*' to '*a piece of music*'. However, most accepted their SDU rhythm as representative of the temporal distribution of their daily lives. Regional Subject 1 described his SDU rhythm as *'monotonous but very reasonable and consistent with respect to my expectations'*.[450]

In some cases, experiences of embodiment of the rhythm were also noted: *'... some sounds, such as walking, really evoked through the rhythm, the sensation at that point in the path.'*[451] However, in others, the sounds were criticised for not '*fully representing one's daily activities'*[452], either due to the lack of information provided in the original subject's mapping, or the effectiveness of the sonic code itself.

The identification of each sound of the code was described as easy, largely due to the iconic nature of the sounds and their limited categorisation. However, this also led to the criticism of the code being somewhat 'cliché'. The fact that the activity categories were broad meant that they could not represent all manners of performing the same activity with one icon. e.g. the difference of eating in a restaurant as opposed to eating at home.

Thus greater success of certain SDU rhythms over others can be attributed to certain sounds being more relevant to the particular situations of some participants more than others. It calls for future development of the code in order to incorporate the particular details of a subject's particular activity, while still being easily understood in a more general context.

Another criticism was that certain details were not represented such as short walks and pauses. This was largely due to the temporal reduction of one's day to less than one minute in duration, and the conscious decision to focus only on major activities to reduce complexity. However this temporal limit can be explored in the future, with the inclusion of minor activities and the testing of different SDU rhythm durations.

10.2.2 Time Distribution

'I have understood better the time proportions in my life, and how many hours I work every day.' [453]

[449] Test subject
[450] Subject 1
[451] Subject 5
[452] Subject 7
[453] Subject 8

Sonification also helped subjects reflect on the distribution of their time in the city, with the SDU rhythm making it 'clear' and 'obvious' as to how much time they spent performing different activities. Most subjects noted that they spent a lot of time (and more often than not, 'too much time') commuting on public transport and in the office. The SDU rhythm also helped subjects identify the daily activities which were an important part of their day, with metropolitan Subject 5 noting that it revealed *'… the things that for me are important and which I do not want to give up, like dedicating a bit of time to walk, to friends, and to profit from the many opportunities in the city.'*[454]

10.2.3 Navigation

The SDU rhythm also helped subjects reflect on their navigation in the city – the mode of transport, type of service and routes they chose (or were forced) to take. For example, a regional Subject 2 noted that *'My SDU rhythm made it very sonically clear how dependent I am on the RER and how much time I usually spend in it.'* This can be compared to the experience of metropolitan Subject 5, who reported that *'My SDU shows the fact that I like to vary depending on the situation: metro, bus, walk, rer ... I am not a fan of a particular transport means. I like to vary.'*[455] To urban decision-makers, it clearly shows the effect of the urban structure – whether regional, metropolitan, or local - on one's daily urban opportunities and constraints.

10.2.4 Urban Awareness

'My SDU rhythm helps me to understand how the city really affects on my lifestyle. To take a metro, a bus, to have appointments far apart or close together, immerses my day in the rhythm of the city. This rhythm has to deal somehow with my inner rhythm with the challenge of a dynamic adaptation over time. Sometimes this comparison has positive effects and at other times disastrous results.[456]

The SDU rhythm prompted subjects to reflect upon their time was being spent and why. Peripheral Subject 4, who works as a freelance teacher and is thus obliged to travel between jobs throughout the day, realized that '*I am forced to spend a lot of time in the metro because of the distribution of the city and the long distances.'* On the other hand, inner-city Subject 8, who lives an 8 minutes walk away from his work, realized that *'I can work more, because I spend little time travelling.'*
However, this question also brought to the fore the social and political aspects of our daily lives, which can often overshadow any opportunities that our physical urban structure may afford. Both inner-city subjects, despite being able to avoid spending time on public transport, realized that in the end *'The city has little effect on me, because I'm working many hours.'* [457]

[454] Subject 5
[455] Subject 5
[456] Subject 5
[457] Subject 8

10.2.5 Learning from Listening

Listening to one's daily urban rhythm also served as a reminder of paying attention to one's rhythm in order to not lose what we enjoy: *'Listening to my SDU, I remembered, now that I work, how much I like to walk and to dedicate a bit of time to this simple stroll.'*[458] Regional Subject 4 noted that listening to her SDU rhythm allowed her to understand her day in segments instead of as a continuous flow, while metropolitan subject NG noted that it provided her with a point of view external to her actual rhythm. Overall, the SDU rhythm was recognized as a '*good means of auto analysis*'. [459]

10.2.6 Instigator of change

'It does make me even more aware of the constraints imposed by my RER-dependence, and also makes me wish I could spend more time walking, which is something that I usually really enjoy doing.'[460]

Hearing one's daily urban rhythm provoked a desire for change in several cases regarding how they spent their time and the overall composition of one's day. There was a general consensus by the owner's of the regional and peripheral rhythms that they wanted to commute less on public transport, in order to have more leisure time. Those who spent all day in the office, after listening to the proportion of one's day in front of the computer, wanted to work less and have more variety and breaks. While obviously depending on the personal interests of the subjects themselves, the SDU succeeded in providing a reflection on ones daily urban choices – or lack thereof.

Conclusions: Sonified Daily Urban Rhythms

From the first part of this Sonified Rhythmanalysis, we can see how the sonification of one's daily urban rhythm provoked a reflection of subject's on their urban rhythms, infrastructure and lifestyles. It also provoked the curiosity in the rhythms of others: *'I would be more interested in listening to the daily urban rhythm of someone else.'*[461] This comparative aspect afforded by sonification will be explored in the following section, involving the identification of one's SDU rhythm amongst several others.

[458] Subject 5
[459] Subject 5
[460] Subject 2
[461] Subject 1

10.3 SDU Rhythm Recognition

In the third and final part of this listening experiment, we investigate the ability of subjects to recognise their sonified daily urban rhythms. After having already listened to their individual SDU rhythms in the previous experiment, participants were asked to identify their sonified daily urban rhythms amongst a group of three SDUs. The objective of the exercise was to understand how easy or difficult it was to identify one's rhythm and also to understand the comparative effect of listening to other rhythms.

See *Appendix 4: Questionnaires & Experiments (Questionnaire 2B)* for further details concerning the experiment and the participants' individual comments.

10.3.1 Ease of identification

There was a 100% success rate in rhythm identification, with 8 out of 8 subjects giving a rating of 'Easy' on a 5-tiered difficulty scale ranging from 'Easy' to 'Difficult.' No difficulties were reported in recognizing one's rhythm, nor improvements suggested.

The participants attributed the identification of their sonified rhythms to memory '*but also by trying to reproduce in my mind the sound according to my day schedule.*'[462] Identification of their individual activities (e.g. running) as well as exclusion (e.g. not working in an office) was also a popular technique.

10.3.2 Comparative listening

The effect of listening to other rhythms produced expected comparative remarks concerning differences in variety, length and frequency. The SDU rhythm made these differences evident: *'It made it very clear how much variety my rhythm lacks in comparison to the other two'.*[463]

This comparative exercise also produced some interesting emotional reactions. Those with the regional rhythm, who had described their SDU's as monotonous, preferred the ones with more variety: *There was much more variety, less commuting and visits to public places and markets in the second and third one. I would much prefer them!*[464]

The inner-city subjects who were not reliant on public transport appreciated this fact and realised how their live-work locations allowed this. As noted by Subject 8, *'I saw that I don't take so much public transport like other people, and this is nice!'*

[462] Subject 1
[463] Subject 2
[464] Subject 1

10.3.3 Comparative change

The effect of listening to other rhythms increased participant's helped them realise what they did and did not have. While some subjects were resigned to the limits of their urban infrastructure *('There isn't much that I can change in my actual daily routine, since it's totally shaped by work and the RER. If I could, though, I would definitely add more variety.'*[465]*)*, in others it provoked a desire for change. Those who travelled alot expressed their desire to spend less time in public transport, while those who spent most of their day working and commuting, desired more variety and entertainment. On the other hand, Subject 5 who was not working at the time, realised she missed the 'sound' of the office or classroom in her daily rhythm and expressed her desire to reintroduce it into her day. Thus in addition to being a tool for 'auto-reflection', the SDU's of others can become a tool of inspiration.

10.3.4 Future developments

Finally, participants were asked to suggest future developments of this exercise. One application included listening to the evolution of their rhythms over time: *'I would like to listen and compare the signification of different days of my week or see its evolution from day to day, month to month or year to year... '*.[466] Subject 5 expressed the curiosity to listen to more people's rhythms and suggested the sociological applications of this exercise.

Discussion: Towards a Sonified Urban Rhythmanalysis

These initial experiments have shown that sonification can be an effective way of representing one's daily urban rhythm, with almost a 100% success rate in correctly identifying the initial sonic code, and all participants easily recognizing their rhythms. This can be attributed to the effectiveness of iconic sounds, and potentially their embodiment in rhythm.

Furthermore, participants' comments regarding their opinion of their daily rhythms were consistent with their initial mapping exercise. For example, those unsatisfied with their commuting time were still unsatisfied after listening to it. However, sound was able to better evaluate their time spent commuting or working, eliciting comments such as '*I commute too much'* and *'I work too much'*.

At the same time, the ability of sonification to communicate other people's rhythms provoked reactions concerning the variety of one's day, with those having a number of activities being the envy of those who worked monotonously for 6 or 7 hours. From both the initial listening experiment and the changes provoked due to comparative listening, it can be seen that sonification has the ability to help in the understanding of one's own rhythms as well as those of others. With further refinement of the sonic code, the sonification of rhythm shows great potential in developing the technique of *Rhythmanalysis* into an 'analytical science' as proposed by Lefebvre.

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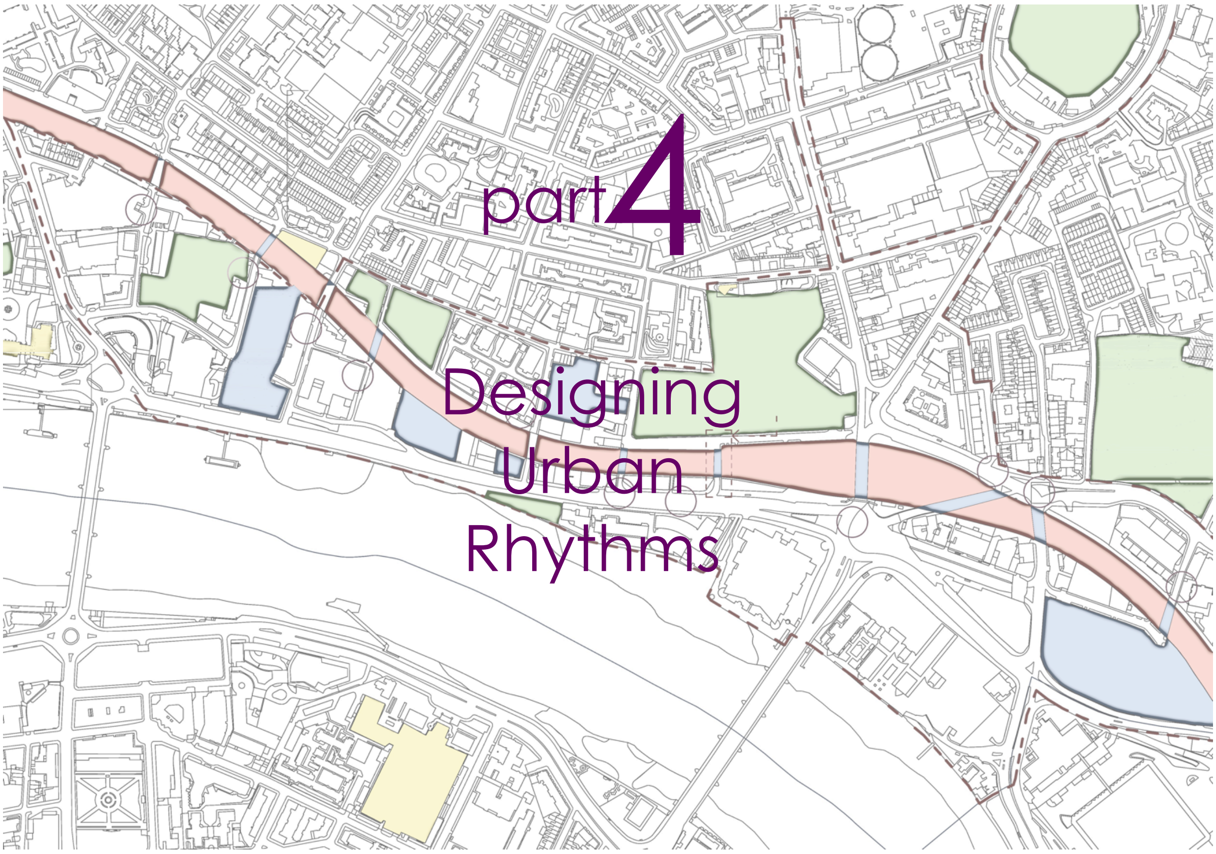
[465] Subject 2
[466] Subject 1

part 4 Designing Urban Rhythms



Introduction

In Part 4, we attempt to ‘design’ the urban design rhythms previously identified. We propose the use of musical structures to inform the design of urban experience. Building upon previously identified parallels between the musical score and the architectural or urban plan, we continue our exploration of the masterplan as an open, graphic musical score. However, this time, we reverse the process, producing graphics from sound, rather than sound from the graphics.

In order to explore the potential of this rhythmical approach in addressing current urban design issues, we will use SUM as a primary design tool for a current urban design project. We have chosen the 2013 international call for design proposals for Vauxhall, an area of London which has been identified as in need of regeneration due to disconnectivity.

We then use the SUM tool to generate an urban design based on that of a piece of music significant to the site - the premier of Handel’s Music for the Royal Fireworks. First, we import the music of interest as spatio-temporal vector paths, and apply it along paths of interest on the existing site plan. We then develop an audio-visual language, in order to translate the relevant sonic parameters of the music into the desired urban design elements. The aim is to generate a graphical urban design from the temporal structure of music.

In the final chapter, we obtain input from various urban design professionals on how they may envision using the SUM tool in their future design work, and discuss the potential contributions of SUM for future urban design.

11 SUM as a Design Tool

So far we have utilized SUM as an image sonification tool for the representation of the graphic urban masterplan. In this section, we explore how sonification can be used in the urban design process itself, as a temporal approach to graphical urban design and composition. In order to demonstrate the use of SUM as a design tool, we apply it to an urban design project, which is represented in more detail in Appendix 5.

11.1 Urban Design Project

As a contemporary case study, we have chosen to apply it to a current design competition, *Vauxhall: The Missing Link, an 'Urban Design, Landscape, Architecture and Public Realm competition*'.[467] Using SUM, in this section we will attempt to compose this '*Missing Link'* temporally, by generating its rhythms musically.

11.1.1 Project context

Vauxhall is a central neighbourhood on London's South Bank. It is identified as a key player in the future growth of London, with 16,000 new homes and up to 25,000 new jobs expected, along with an extension to London Underground's Northern line.

The clients of the project consist of Vauxhall One, RIBA, Landscape Institute and the Garden Museum, whose urban objectives include: place making and place management; making Vauxhall feel safer; integrating the day and night-time economies; building employment and training opportunities; improving the public realm; and improving connectivity and rebuilding a sense of place.

11.1.2 Background of the Site

As seen in the site-plan in Figure 11.1, the public realm is dominated by a 'notorious traffic gyratory' which creates a barrier to the river. This disconnected environment makes it difficult to navigate, with green spaces being hard to find and creating an overall unwelcoming environment for pedestrians.

However, in the 18th century, Vauxhall was considered a fashionable area. It is where Handel's Music for the Royal Fireworks was debuted and this history is still highly valued, with an outdoor Handel concert scheduled for June 2013.

Currently, Vauxhall is home to MI6, the Battersea Power-Station, as well as having a city-

[467] http://www.ribacompetitions.com/vauxhallthemissinglink/brief.html [Accessed February 2013]

wide reputation for its thriving nightlife. The neighbourhood is recognized as the '*missing link between the New US Embassy Quarter and London's South Bank, with its theatres and concert halls.'*[468]

Vauxhall is also identified as an area for future growth, with current investment in new buildings and development schemes by world-renowned architects, including Rogers Stirk Harbour and Foster and Partners. The opportunities for innovative green spaces and streets to link them is clear, and *'Vauxhall is recognized as an area of huge new opportunity in London'.*[469]

Furthermore, Vauxhall is envisioned as a new cultural heart for London, with existing cultural attractions such as the Tate Britain, as well as more contemporary artistic hubs such as Damien Hirst's new gallery. Vauxhall is described as undergoing a *cultural renaissance*.

11.1.3 Urban Design Objectives

'*an identifiable pathway and narrative through the area, linking the railway arches, green spaces and public art into a distinctive place once again'*.[470]

To reconnect the disjointed parts of the neighbourhood, the existing parks, gardens and walkways, an open call for a creative urban and landscape scheme took place in early 2013. A *Cultural and Green Trail* from Vauxhall Park to Lambeth Palace was requested as part of an international design competition. Suggestions included streetscape strategies, street trees and planting ideas, and pocket parks.

In collaboration with Architect and Urban Designer Jennifer Scott from Perth, Western Australia, we attempt answer this call for a 'coherent and exciting' urban design interventions by using SUM as the primary generator of urban design project. Following is an explanation of the methodology behind our rhythmic approach to urban design, with more design details available in *Appendix 5: Urban Design Project*.

[468] ibid.
[469] ibid.
[470] ibid.

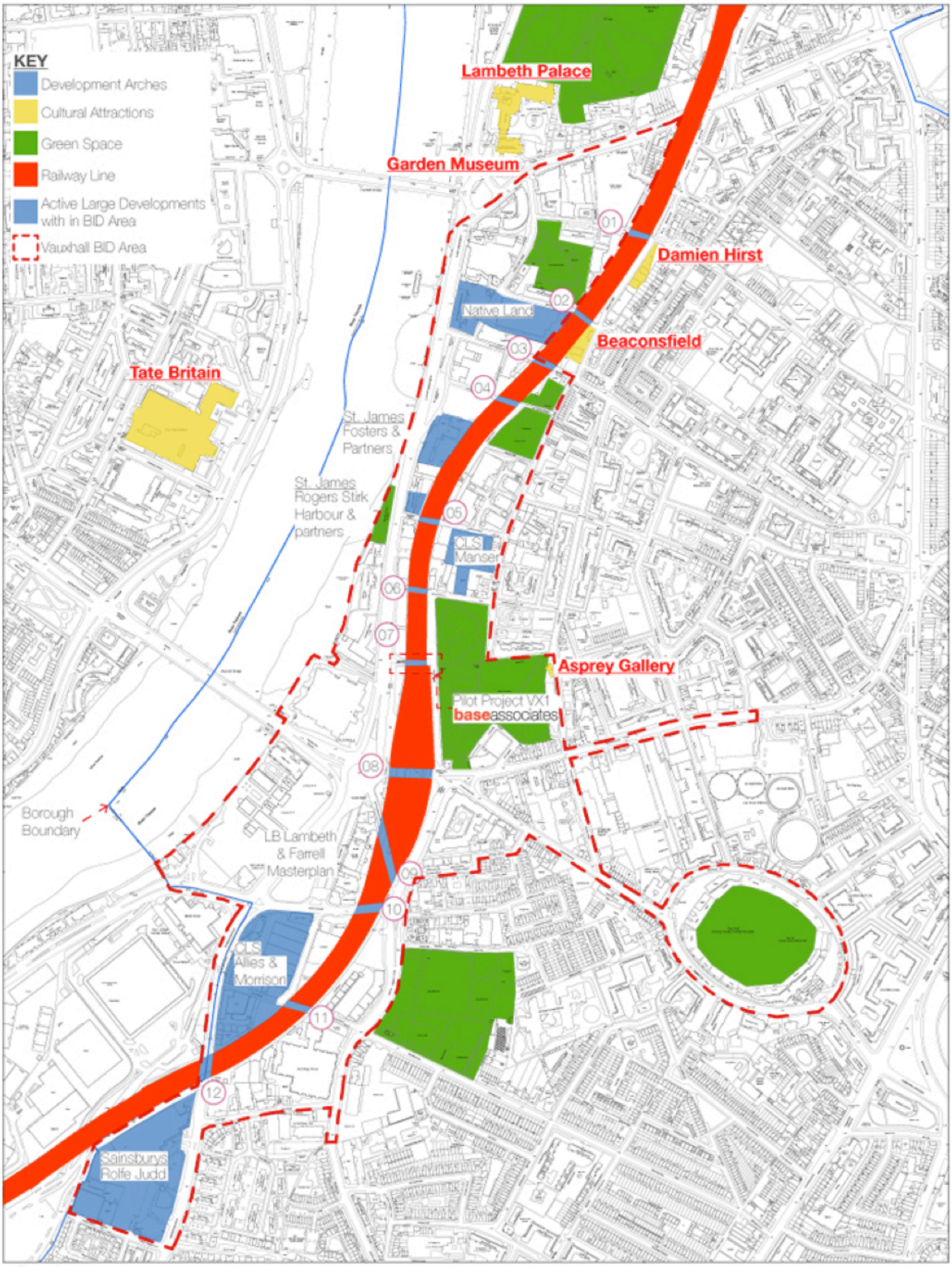


Figure 11.1: Vauxhall Site plan showing existing and current developments [471]
a) railway (red); b) public parks (green); c) cultural attractions (yellow) and d) new developments (blue), including the spine of railway arches

[471] ibid.

11.2 Composing Urban Experience

In order to compose the experience of the site, we draw on two pieces of site-specific music by George Frideric Handel: *Music for the Royal Fireworks in D, HWV351*; and *Water Music Suite No.2 in D, HWV349.*

11.2.1 Site-specific Music

'In 1749 Handel's Music for the Royal Fireworks was given its debut in Vauxhall.' [472]

Figure 11.2: The Royal Fireworks as seen from the Thames[473]

In homage to the history of the site, we have chosen to explore Handel's *Music for the Royal Fireworks* as the generator of the design. This suite for wind band ensemble was commissioned by King George II to celebrate the end of the War of the Austrian Succession and the signing of the Treaty of Aix-la-Chapelle. It was to accompany a firework display in Green Park, London, and rehearsed in Vauxhall Gardens in 1749 (depicted in Figure 11.2). We will also draw on his collection of *Water Music* suites, commissioned more than 30 years earlier in 1717 by King George I and performed on a barge on the Thames. Both being written for the open air, the two pieces are often performed together. The legacy of Handel on the site of Vauxhall is still strongly held, with an outdoor concert being scheduled to be performed this year (June 2013), together with fireworks.

[472] ibid.
[473] image source: http://en.wikipedia.org/wiki/File:RoyalFireworks.jpg [Accessed March 2013]

11.2.2 Visualization of the Music

Here we use SUM to visualize both the rhythmic and morphologic structure of both Handel's *Music for the Royal Fireworks* and *Water Music.* We have chosen to focus on the fourth movement of the Firework suite, *La Réjouissance*, meaning the 'rejoicing'. We anticipate that the rhythm and tempo ('allegro') of this well-known piece will generate an appropriately lively graphic composition. Handel's La Réjouissance can be heard here [474]:
https://www.dropbox.com/s/oceam5g1e3vs35g/Handel_Fireworks_LaRejouissance.mp3
and Handel's Water Music 'Alla Hornpipe'[475] here:
https://www.dropbox.com/s/o72lndcxas9yw9s/Handel_Watermusic_AllaHornpipe.mp3

First, we import Handel's music in MIDI format into SUM using SUM's MIDI importer. Each part of this file is transformed into a separate vector time path, with each sound event becoming a point along this path. Thus the rhythmic structure of the piece can be seen as a pattern of points, as observed in Figure 11.3.

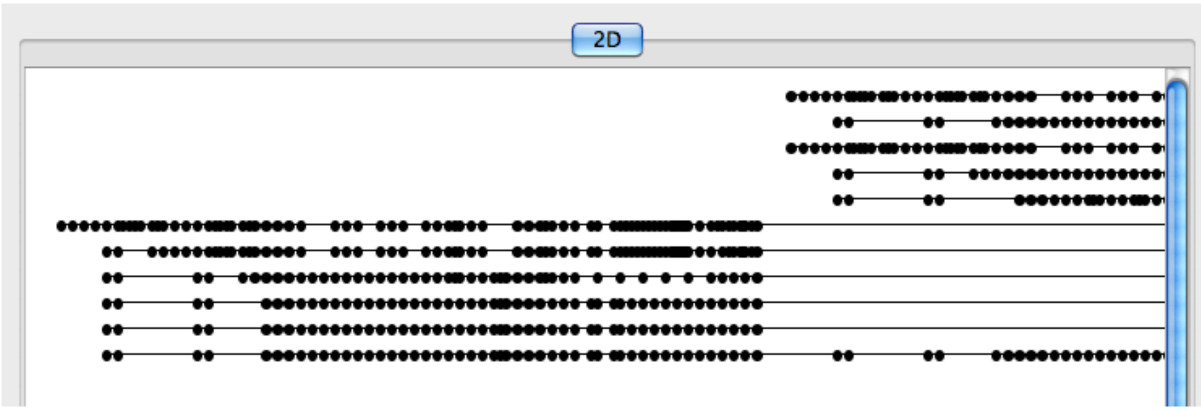


Figure 11.3: Representation of beginning of Fireworks as a series of vector time paths

A piano-roll can then be generated from these paths, allowing us to observe the distribution of instrumental pitch over time as a density of lines of varying duration. (Figure 11.4)

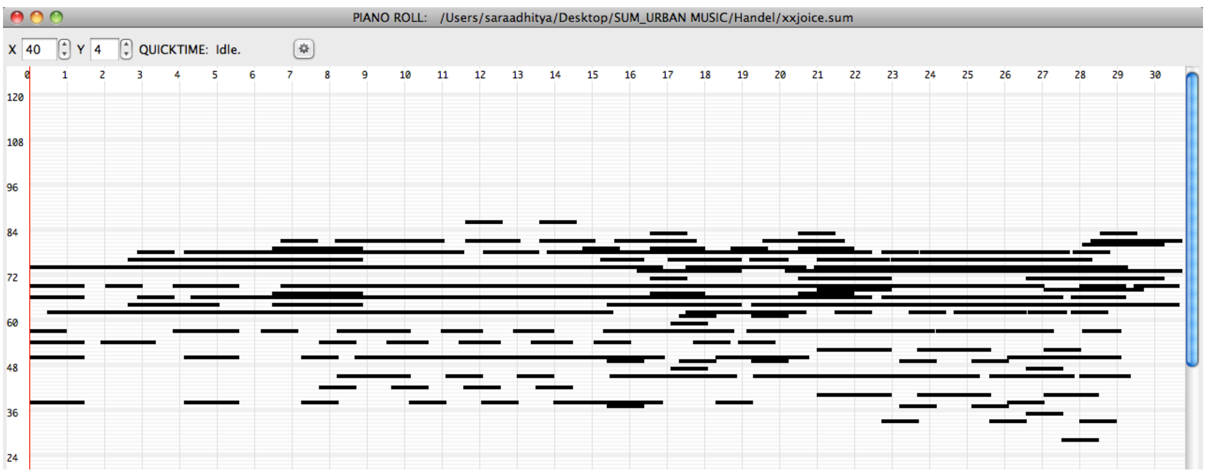


Figure 11.4: Resulting piano-roll of beginning of Fireworks

474 http://classic-online.ru/uploads/101200/101113.mp3 [Accessed 29 March 2013]
475 http://classical-music-online.net/download.php?file_id=72127 [Accessed 29 March 2013]

This allows us to graphically compare and contrast their spatial and temporal distributions over the length of the piece. By color-coding different parts of interest, the relationship between them can be observed. We assigned the 2 main voices of Fireworks different colours (green and orange) and the alternation between them can be clearly seen in Figure 11.5.

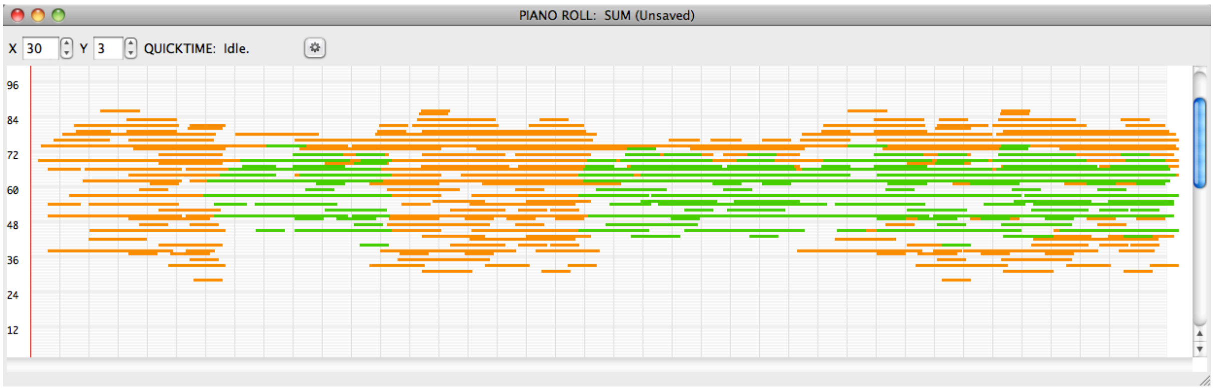


Figure 11.5: Colour-coded piano-roll of the entire movement of La Réjouissance, Fireworks

The same approach was applied to the second movement of Handel's Water Music Suite No.2 in D, *Alla Hornpipe*, with the different parts shown as different shades of blue in Figure 11.6.

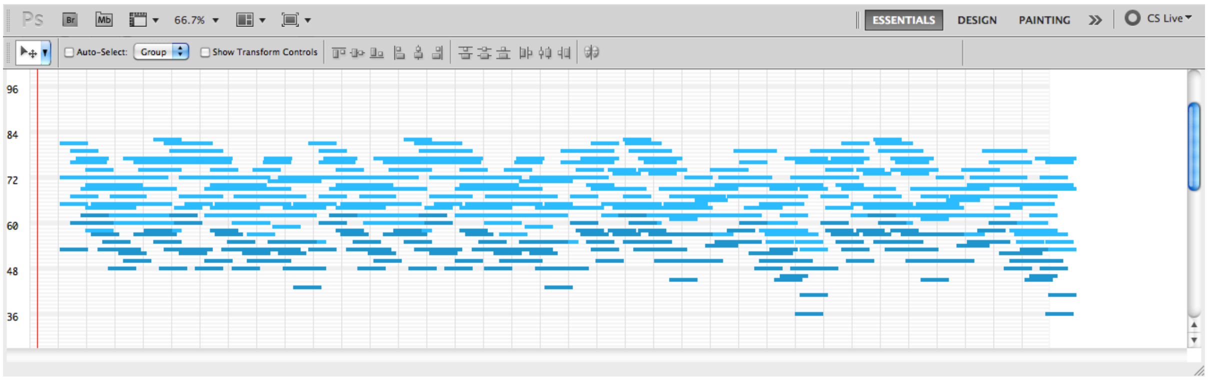


Figure 11.6: Colour-coded piano-roll of Water Music

This allows the compositional structure of the two pieces to be easily compared at different temporal scales. When condensed in time, this morphology becomes even more evident. As seen in Figure 11.7, Fireworks demonstrates pronounced pitch-changes divided in two distinct sections, while Water Music remains more evenly distributed in pitch and time. The two pieces will be later applied according to the following urban design strategy.

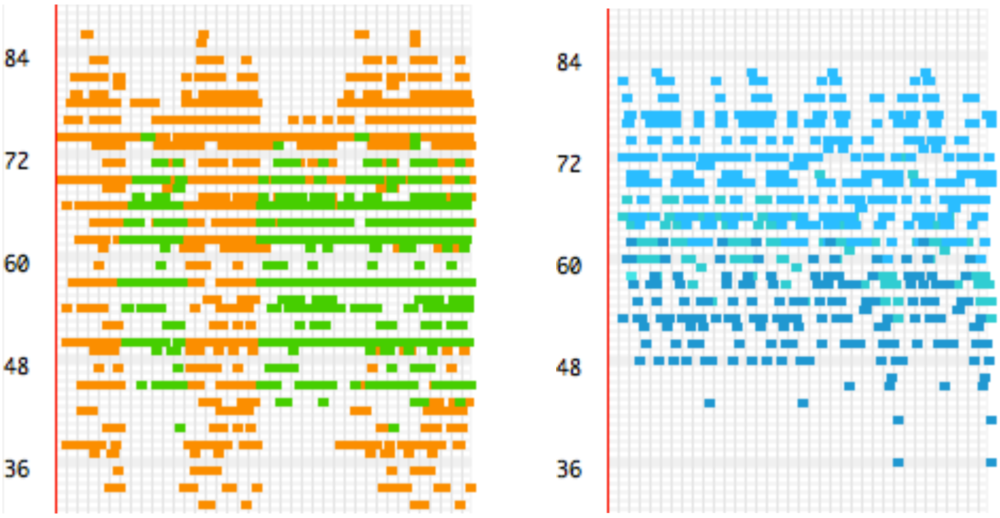


Figure 11.7: a) Visualisation of Handel's Fireworks vs. b) Water Music

11.3 Urban Design Proposition

In this section, we demonstrate how SUM can be used in the generation of an urban design. It should be clarified that SUM is not intended to replace the role of the urban designer in evaluating urban needs, but rather is useful in generating urban experience on a more detailed level. Thus, we must first analyse the existing site conditions and delineate the site's opportunities and constraints. As identified by Vauxhall One, a series of green spaces (in green) and new developments (dark blue) are disconnected from each other and the river's edge (cyan) by the railway line (red). Our urban design strategy thus aims to connect these opportunities with each other, as well as to reconnect them with the Thames. We propose the development of a series of green links (Figure 11.8) as well as an activated waterfront walk. (Figure 11.9)

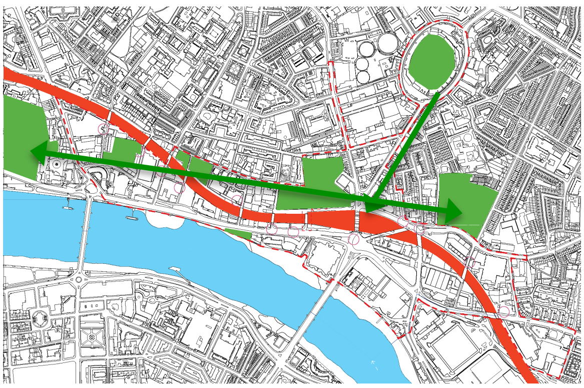


Figure 11.8: Proposed green links

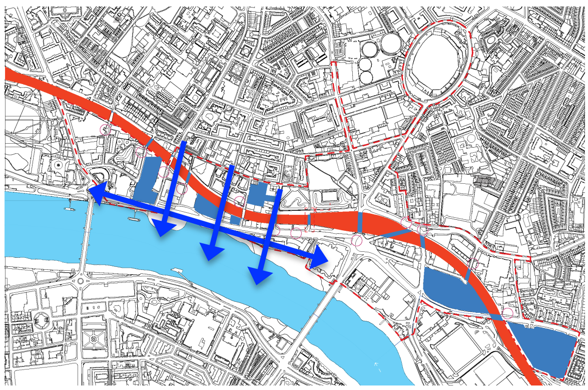


Figure 11.9: Proposed connections to waterfront

This overall structure can then be used as the basis of our SUM-generated urban design, informing the spatio-temporal composition of urban design elements in an attempt to answer the question of *'why you would want to walk and cycle from Vauxhall to the South Bank'*[476].

[476] ibid.

After importing a raster image of the existing site into SUM, we then defined the paths of interest according to our strategy. Using the MIDI importation function, we map the desired music to these paths. We have chosen to apply the Fireworks music to the green links along the railway line (see Figure 11.10), and generate a tree-planting strategy according to its rhythm.

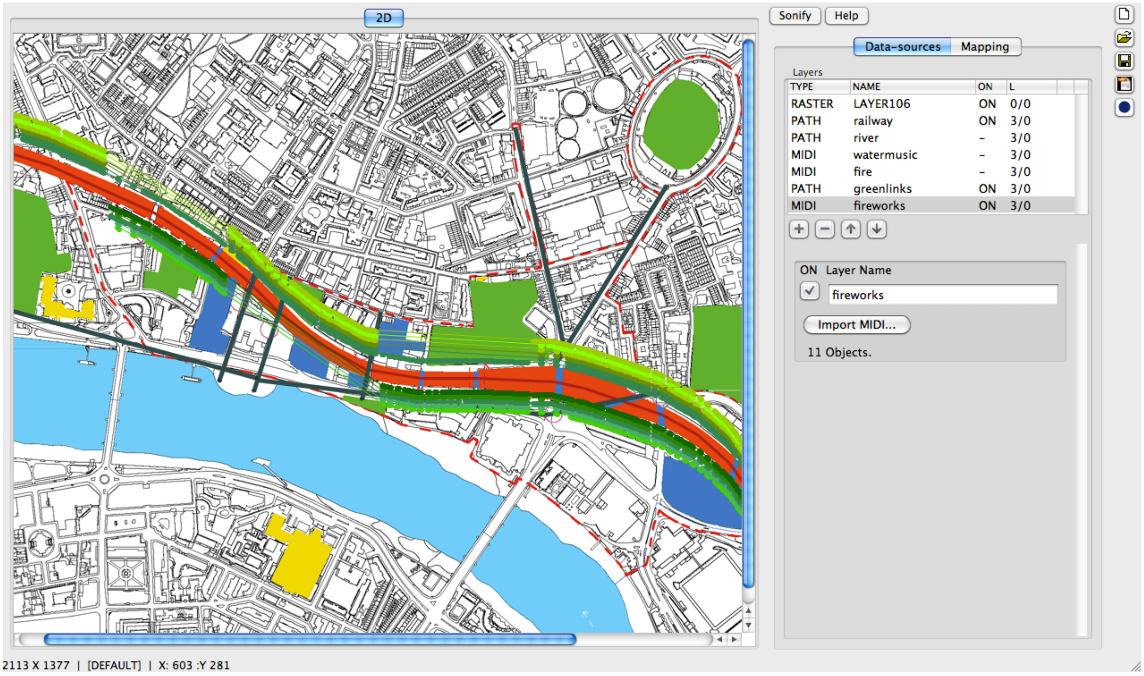


Figure 11.10: Application of Firework music to identified greenlinks in SUM – the different paths and their rhythmic structure are used to inform the greening strategy

We then applied the Water Music along the river's edge (Figure 11.11), generating the rhythm of the waterfront development. The morphology of the music becomes a series of pontoons extending from the new links into the river, interacting with the Thames as was done during Handel's time from the royal barges. Possible development perspectives are shown in Figure 11.12.

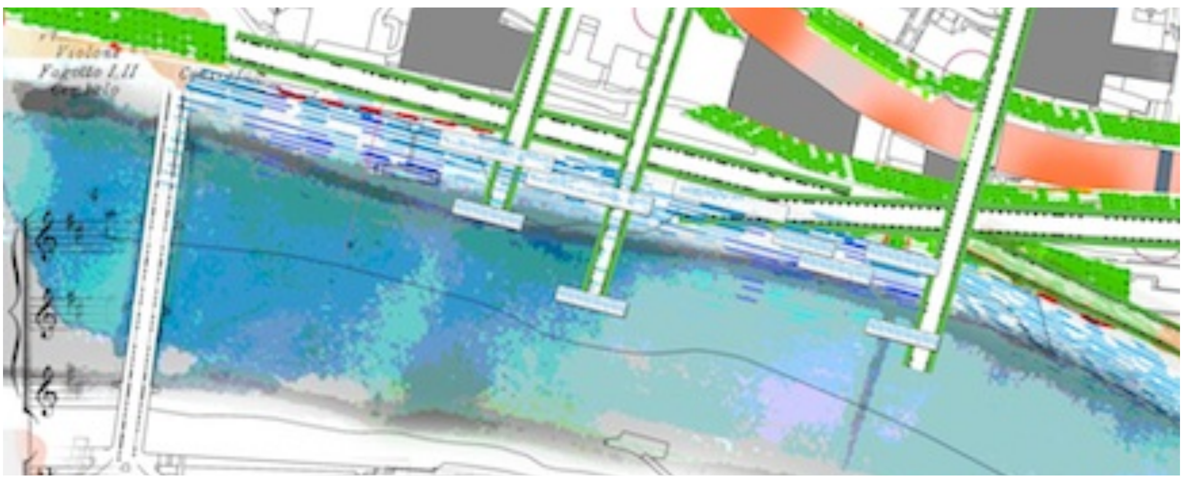


Figure 11.11: Application of Water Music to the water's edge and beyond – informing interaction with the water

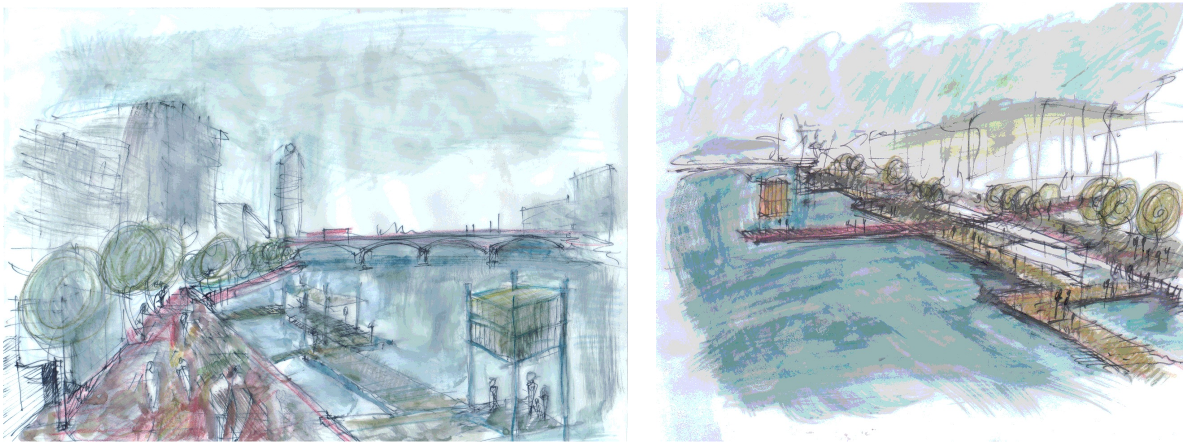


Figure 11.12: Artist's renditon of the development of Water Music as a riverside walkway [477]

Finally, we apply the spatio-temporal distribution of the music to generate a cohesive landscaping layout for the various green spaces. The result is presented, in combination with the other elements, in the conceptual masterplan in Figure 11.13. Further details of the design are available in *Appendix 5: Urban Design Project*.

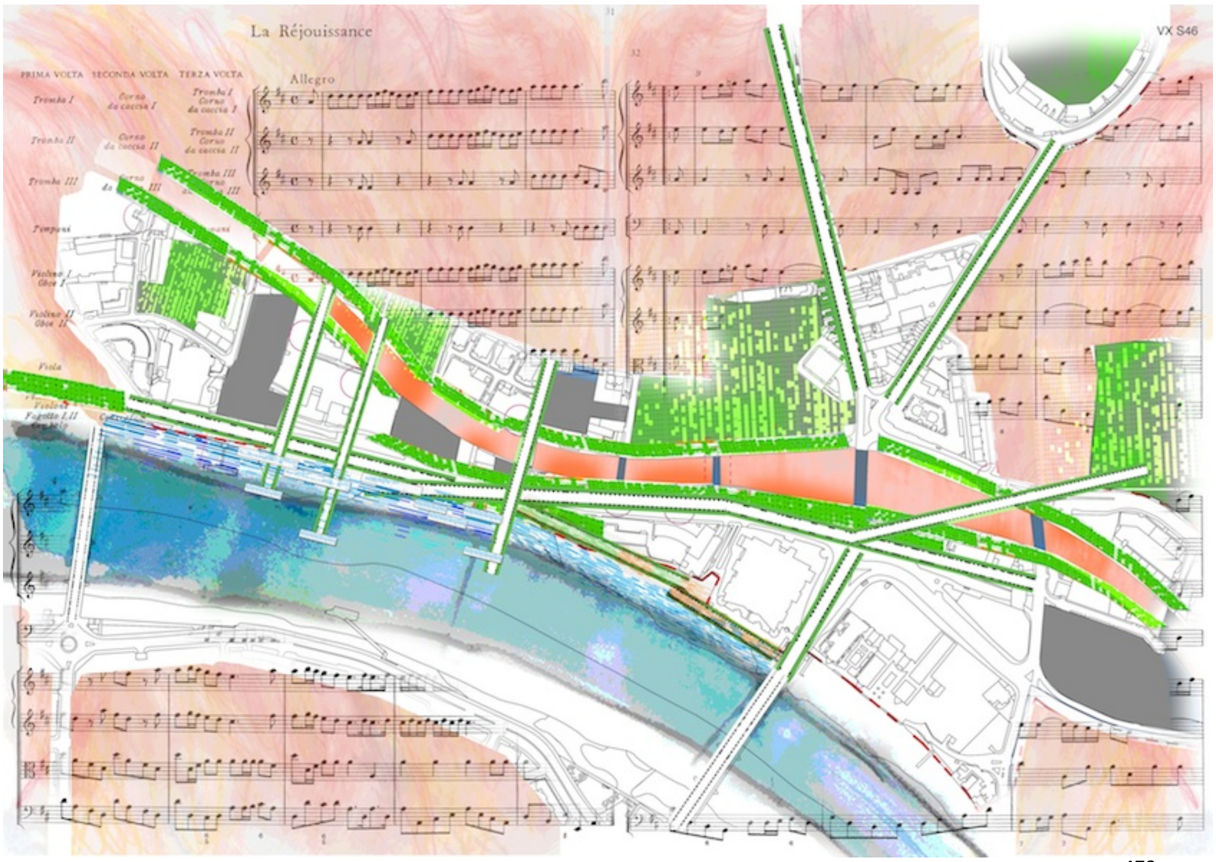


Figure 11.13: Overall conceptual masterplan for Vauxhall based on Handel's music [478]

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[477] Sketches by J.Scott

[478] Adhitya, Scott

Discussion: A rhythmic approach to urban design

In this section, we have explored the use of SUM as a design tool. Through the development of the SUM tool from image sonification to graphic design, we have been able to map music (in MIDI format) to user-defined vector graphics and subsequently modify them both spatially and temporally.

To demonstrate SUM's potential in urban design, in collaboration with Architect and Urban Designer Jennifer Scott, we applied it to an urban design project – an urban park for the redevelopment of Vauxhall, London. This design was exhibited in London in April 2013, at the Garden Museum and in an outdoor architectural trail through the Vauxhall area.

However, this is only the beginning of an exploration of how music can be used to inform the composition of urban experience. In the future, we hope to use SUM's Object Illustrator to further explore the generation of a new audio-visual language for urban design.

12 Professional Consultation

Finally, urban design professionals, including Architects, urban designers, planners and engineers, were consulted on their thoughts regarding the potential of the SUM tool for urban design and planning. The comments of six urban professionals from around the world (Italy, France and Australia) are discussed below:

vii. Architect, Paris, France
viii. Planning & Engineering Officer, Perth, Australia
ix. Architect, Treviso, Italy
x. Urban Designer, Perth, Australia
xi. Architect, Forli, Italy
xii. Architect, Paris, France

Their individual comments are available in detail in *Appendix 4: Questionnaires & Experiments (Questionnaire 3).*

12.1 First Impressions

The first impressions to the SUM tool were general positive by design professionals. They responded as both as viewer and designer, suggesting SUM's use as both a practical design tool, an expressive representational tool and as an analytical tool. Planner 2 was to describe SUM as both *'…practical, but incidentally, quite poetic.'*

Practically, all professionals noted the temporal dimension of SUM as something that was usually not represented in a traditional plan, but would allow them to represent more information regarding the urban system and its experience, which is inherently temporal. Urban Designer 4 was to acknowledge that *'SUM brings the aspects of time to the fore. Our traditional representations are a frozen slice of time, so it is something too easy to forget in the design process.'*

As a representation tool, SUM was described by Architect 6 to help one better 'imagine' the city by 'living' the plan. The resulting effect was described as providing a more 'human' scale by expressing the impact on the city on its residents. Furthermore, the *'interdisciplinary'* aspect of SUM was appreciated for '*its capacity to be the effective interface of several disciplines',* leading Architect 1 to propose its use in research as well as design.

The various qualities of the SUM tool as seen through the eyes of these urban professionals – its temporality, polyphony and rhythm – will be further discussed below in relation to their potential use for urban representation and design.

12.2 Urban Representation

Each of the urban professionals were asked to comment on their opinions regarding the use of SUM in the representation and communication of their architectural or urban projects.

Architect 1 was to identify two ways SUM could be used in urban representation: first, as an 'appreciative tool' in the representation of an already-conceived work; and second, as an 'analytical tool' which could be used during the design process itself. However, as recognized by Architect 1, this would require the establishment of a protocol regarding the relationship between the "signifier" and the "signified".

Planner 2 admitted that SUM made her realize 'what was missing ' in the current maps she used. She called for '*the need for planners / urban designers to move away from static maps, because life and especially transport are not static, yet the maps and plans we use are.'*

Architect 3 identified the temporal aspect as useful in representing the experience of a project. He proposed the use of realistic sounds to represent its realistic components, produced a sort of 'sound rendering', and 'abstract' sounds to represent its 'hidden' aspects, producing a 'sound diagram'.

Urban Designer 4 recognised the role SUM could play in the appreciation of urban rhythm, with its capacity to bring to mind experiences and memories of the city and how it works.

Architect 5 suggested that SUM could help communicate a map to the blind. He identified SUM's ability to represent time, and was interested in understanding how much influence sound had on one's perception of the city.

Architect 6 greatly appreciated the temporal nature of SUM to represent an urban experience in time. This meant that the experience an urban project could also be inscribed in time, allowing the communication and understanding of a project by those who are not accustomed to the reading or the interpretation of two-dimensional plans.

12.3 Design and Composition

Regarding the design and composition of urban experience, designers identified a number of different ways in which SUM could be useful.

For Architect 1, its use in design was again of a dual nature: *'It is not difficult to imagine that SUM could be useful in the urban design process either as an "appreciation of existing spaces" or as a "generator of new and meaningful form".'*

Planner 2 felt that SUM could help in the appreciation and understanding of the way a city functions, 'a*nd thus help us "see" what we're working with'*.

Architect 3 identified SUM's '*rhythmic coupling of audio-visual material'* as allowing designers the possibility to shape urban experience, as well as to verify the layering of elements and their patterns over time.

Urban Designer 4 was able to imagine a number of aspects for the utilization of SUM in design, including its application to different urban settings and design options.

Architect 5 posed the question, '*should we use music composition rules to draw the city, or should we use architectural rules to play music?*' To him, the application of SUM in practice presented many theoretical questions. He saw in SUM the possibility to develop a 'new alphabet' or compositional language to designing the city, referring to Kevin Lynch's *"The image of the city*".

Architect 6 was to acknowledge SUM's ability to represent, and thus draw attention to, the relevant qualities of urban spaces, whether open or closed, and the effect of different speeds on its subsequent experience, whether by a pedestrian, cyclist or driver. He also identified the ability of SUM to communicate an urban experience at any graphic scale: *'It allows you to enter a scale that, due to the distance, can make a small scale such as 1: 500 or 1: 1000, very difficult to imagine the reality of the street or the daily experience.'*

12.4 Temporality

Given the static nature of the graphic masterplan they usually work with, the urban professionals were asked what they saw were the benefits of the temporality provided by SUM.

Architect 1 described SUM as 'demystifying' temporality, by allowing time to be collected, represented, analysed and recomposed. He recognised SUM as being able to connect the spatial composition of objects with their temporal implications, noting that *'The SUM tool renders tangible the fact that objects composed in geographical space are inherently objects composed in temporal space.'*

Planner 2 supported the fact that SUM drew the attention of planners and urban designers away from 'static maps'. After all, '*life and especially transport are not static, yet the maps and plans we use are.*'

Architect 3 similarly appreciated SUM for its ability to transform the static into the dynamic. These dynamic elements were described as usually 'hidden' due to their static representation, and thus often not considered by planners and designers.

Urban Designer 4 also encouraged the fact that SUM allows '*everyone in the design process access to an understanding of time/temporality/rhythm. It puts it on the table and not forgotten.*'

Architect 5 appreciated SUM's ability to represent the city's rhythms, and in particular the changes of a space over time (in minutes, hours, days, nights, seasons, years...). He suggested SUM's use in the representation of the rhythms of different spaces, i.e. the *rhythms of place*.

On the other hand, Architect 6 focused on SUM's ability to represent the *rhythms of path*. By providing the element of time, the experience of particular trajectories of a project can be represented. This was explained to be *closer to reality* than a photo or drawing, as each person can relate the sounds to *his own experience of the city*, allowing us to generate our own internal 'images'.

12.5 Polyphony

The utilization of the polyphony afforded by SUM received a variety of responses by the design professionals, largely depending on their specialisations.

Architect 1 felt that this polyphonic dimension was both 'liberating' and 'limiting' – *'liberating in the sense that we cannot see all graphic layers at the same time, but it is possible to listen to a polyphonic composition. It is limiting in the sense that one can not listen "ad-infinitum" where as one can look at graphic layers as if they are suspended in time.'* Combining sonic polyphony with the usual graphic 'staticness', SUM provides both ways of reading the city, necessary in urban analysis.

Planner 2, a transport planner and traffic engineer concerned with the assessment of large subdivisions and structure plans, described her job as quite dry as well as abstract in approach. She envisioned that SUM's polyphony would be helpful in helping her better "see" the interaction between commuters, and noted that '*the incorporation of sound (and motion) would make the work I do feel more real, and I would find it easier to engage with my work'*. Thus sound can be seen to provide a 'human' element to the technical maps of planners, aiding not only their communication to the public but to the professionals themselves.

Architect 3 acknowledged SUM as a powerful representation tool and that *'representation is fundamental for analysis'* while Urban Designer 4 recognised the usefulness of polyphony in representing layers of movement.

Both Architects 5 and 6 identified the ability of sonic polyphony to provide more information and represent things in further detail, through its inherent capability to represent more dimensions simultaneously.

12.6 Rhythm

When asked how the appreciation of sonic rhythm in SUM could impact on their approach to architectural and urban design, a variety of responses were received.

For Architect 1, rhythm acted both as a reminder for designers to engage the temporal dimension in design, as well as providing a concrete means to do so. As an example, he suggested that '*it would be impossible to conceive of a pedestrian promenade without bring in consideration the pace at which we walk.'*

Planner 2 felt that the sonic rhythm helped make her work more 'real' and less abstract, and thus easier to engage with. She notes that '*I would not have to try so hard to imagine what the plan would look like on the ground, as I would be given more to work with.*' She felt that such an approach would help her consider land use and transport integration in a more 'common-sense' way than achieved simply by following policy rules.

Architect 3 felt that rhythm would '*open architects' ears and mind towards sound and time*', which were recognized as important components of planning.

Urban Designer 4 again identified the ability of the rhythm to make movement part of the drawing, and thus help one conceptualize more collectively in the design process.

Architect 5 also felt that rhythm could become another design instrument, to determine rules to apply to the project. He expressed the desire to use SUM in his future projects.

Like Planner 2, Architect 6 noted that the rhythm made the architecture less abstract. Rather, it helps connects us more easily with the future temporal experience of the project.

12.7 Future Applications

Finally, all were asked how the SUM tool could be useful in their next design project or planning scheme.

Architect 1 indicated that SUM could clearly be used in projects where "movement" is a central theme, such as the design of urban promenades, bus stations, railway stations or highways. He also envisioned its use in the composition of façades and/or landscape layouts.

Planner 2 suggested that it could be useful simply in drawing more attention to the important dimensions of movement, interaction of land use and people movement. She expressed a desire to use it herself and indicated that it would provoke practitioners to start thinking about planning in a more holistic way.

Architect 3 identified a number of urban elements which SUM could represent, both measurable and non-measurable, including formal aspects such as materials and colours, as well as data flows such as population, transport, mobile data and money.

Urban Designer 4 suggested SUM's use in design option analysis, and was interested in capturing the memories, understandings and readings of both the existing and proposed city.

Architect 5 proposed the playing of the city from other points of views, including its streets and perspectives, as well as in 3 dimensions.

Last but not least, Architect 6 was interested in using it to show the client how a project relates to its environment, including nearby activities, e.g. '…a school on one side, a park on the other'. He notes that *'With SUM, we can really show how the architectural project responds in a concrete way to its environment*'.

Discussion: The future of SUM in Urban Design and Planning

From the wide variety of responses and ideas that SUM has so far received, the rich potential of its application in urban design and planning is promising. As noted by Planner 2, *'…I can see a future for sound to be incorporated into planning / urban design'.* Which direction SUM will take - as a representation tool, a design tool, or as an analytical tool – will largely depend on the direction the urban design and planning professionals themselves choose to take.

13 Conclusions

Towards the spatio-temporal composition of the urban environment

In this thesis, we have identified rhythm as an important quality of our urban environments and explored various urban rhythms through the use of sonification. After first identifying the different types of rhythm which exist within the city - environmental; morphological; transport; activity; and urban design - we then sought to ‘capture’ them as first proposed by Lefebvre in his theory of Rhythmanalysis. We proposed the acoustic communication technique of sonification – the representation of data through auditory means – as an appropriate means of their articulation.

With the main representation technique of urban designers and planners being the graphic urban masterplan, we developed a Sonified Urban Masterplan (SUM) tool for the sonification of existing urban plans as well as the composition of new ones. The development of the SUM tool as an image sonification tool allowed us to translate graphical information into sound. By developing an urban sonic code, we were able to translate the graphic urban elements of interest into sound, and thus articulate their composition in time as well as space. We applied this urban sonification methodology to our case-study city of Paris, generating a Sonified Urban Masterplan which would allow us to listen to the city.

A public survey demonstrated the ability of the SUM tool to represent temporal and polyphonic urban qualities that a traditional masterplan could not due to its static and graphic nature. The emotional, aesthetic and intellectual responses received demonstrated the power of sound to ‘capture’ urban rhythm and communicate urban experience. Many subjects revealed that the sonic dimension to the masterplan increased their awareness of their acoustic environments, their urban experiences, and the overall composition of their urban environments. Furthermore, the variety of suggestions for interactive applications of SUM indicates a desire to participate in the rhythmic composition of one’s city in the future.

We then applied the SUM tool to the analysis of the daily urban rhythms of the city’s citizens, towards the development of a sonified urban Rhythmanalysis. A space-time mapping survey was first conducted in order to identify typical everyday live-work rhythms in Paris and representative rhythms were selected for sonification. Initial listening experiments showed that sonification was an effective way of representing one’s daily urban rhythm, with all participants recognizing their rhythms with ease. There was a strong correlation between the satisfaction, or disatisfaction, with one’s sonified rhythm and one’s actual rhythm. However, sonification was seen to provide a more objective representation of the temporal distribution of one’s day and thus described as a good means of ‘auto-analysis’. A comparative listening exercise ignited much interest in other people’s rhythms and provoked participants to compare their rhythms with those of others, highlighting activities which they missed and provoking the desire for changes they would like to make. Participants also noted greater awareness of the opportunities and constraints afforded by their urban structure. This landmark sonified urban Rhythmanalysis thus showed great potential in increasing awareness of our own urban rhythms as determined by our urban environments, as well as those of others, and can be seen as a significant development of Lefebvre's *Rhythmanalysis* as an 'analytical science'.

We then explored the use of SUM as a design tool, developing its graphical composition capabilities to allow both the importation of music files as well as the generation of vector graphics. To demonstrate the potential of these functions in urban design, we applied it to a current urban design competition for the regeneration of Vauxhall, south of London, structuring pedestrian experience according to the rhythms of a site-specific piece of music. While architects have long drawn on music for formal inspiration, and various attempts have been made to 'score' urban design through abstract graphical notations, the SUM tool allows musical structures to be integrated directly into an existing masterplan. This allows music to be used as a primary generator of urban experience and allows us to design in time as well as space. Furthermore, the ability to develop a library of graphical sound objects will enable designers to develop their own audio-visual language for temporal urban design.

Consultation with various urban professionals showed great promise for the implementation of the SUM tool in the urban design process, for both the representation of existing spaces, as well as the generation of 'new and meaningful form'. Sonification was shown to help with their own engagement with a site and the analysis of its temporal, polyphonic and acoustic qualities. It was appreciated as a more holistic and sensorial approach to urban design, particularly useful in the composition of urban movement and pedestrian experience. Last but not least, the SUM tool was appreciated as a useful tool for the communication of architectural or urban projects to clients.

While the effect of a more rhythmic approach to urban design will take some time to reveal itself, the ability to represent the rhythms hidden in the graphic urban masterplan is a significant step forward in allowing us to take control of the time of our lives. Sonification has shown its ability to express urban qualities such as diversity, density, activity, vitality, rhythm and movement. The SUM tool could thus be used to help citizens decide where they wish to live, work and play in a city, and how they would like to get there. It could also help professionals identify urban areas in need of revitalisation and reanimation, and create more enjoyable connections and pedestrian experiences. With sound being a medium of communication accessible to both the public and professionals, it is envisioned that SUM could help communication in the public consultation and urban decision-making process. As commented by one urban designer, it allows '*everyone in the design process access to an understanding of time/temporality/rhythm. It puts it on the table and not forgotten.*'

The integration of sonification in the urban design and planning process has thus allowed us a point of access to an important indicator of the spatio-temporal quality of our urban environments – urban rhythm. Our Sonified Urban Masterplan exposed the drawn rhythms hidden in our graphic urban masterplans. Our sonified urban Rhythmanalysis revealed to citizens the role of the urban structure in the composition of their own daily urban lives. Our urban design project demonstrated how we can design in time as well as space and compose our temporal experiences like a musical score. We hope that increasing our awareness of urban rhythm, and providing the tools with which to access and design it, will lead to the composition of more sustainable urban rhythms in the future.

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Appendices

Appendix 1: SUM Tool Documentation

User Documentation

SUM Tool

Image sonification - Graphical composition

version 2.99

Sara Adhitya and Mika Kuuskankare

1 Introduction

The SUM tool is a user library with a graphical user interface within the computer-aided composition environment of PWGL. Initially designed for the sonification of images through a user-defined mapping process, it also allows a graphical approach to music composition.

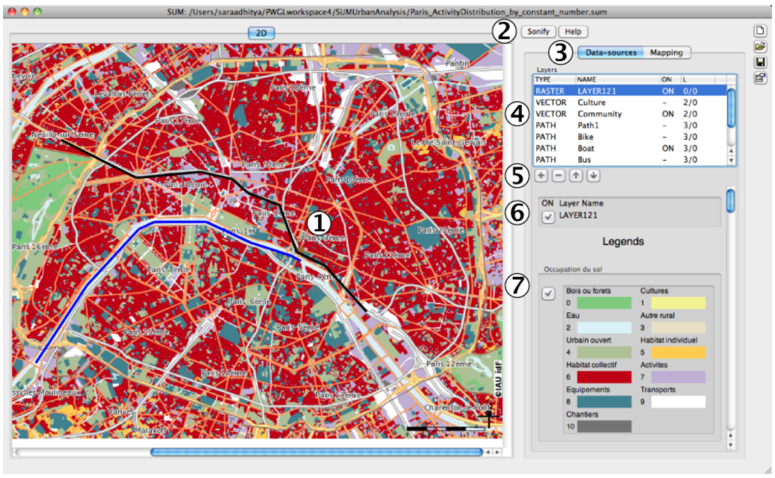


Figure 1: The SUM Tool user-interface

The SUM Graphic User Interface

1. The image viewer

   The image viewer displays the selected layers superimposed on top of each other.

2. The 'Sonify' and 'Help' buttons

   The Sonify button initiates the sonification process and produces the pianoroll. The Help button displays the internal documentation.

3. The Layer/Mapping selector tabs

   The Layer tab manages the image layers. The Mapping tab manages the sonification process.

4. The list of Layers/Mappers

Depending on the selected tab, the list of layers or mappers is displayed.

5. Layer/mapper operations buttons

   These buttons allow one to add, remove and arrange the layers or mapper groups.

6. Layer/mapper attributes panel

   Depending on the selected object (the vector, path or grid layers, and mapper groups) we can rename and save the selected object. We can also turn these objects on or off. In the case of Layers, this controls their visibility. In the case of Mappers, this controls their audability.

7. Layer/mapper/object detail panel

   Here the details of the object in question are displayed.

SUM supports both the importation and creation of multiple image layers (raster and vector) as data input. This data is then retrieved through the drawing of one or more vector paths over the areas of interest, and their graphic attributes mapped to sound attributes results in the generation of audio parts. Thus SUM supports a multi-dimensional spatio-temporal approach to image sonification.

The SUM user-interface consists of two tabs which have the following functionalities, as demonstrated in figure 2.

1. Data-source - for the importation of images
2. Mapping - for the definition of the sonification process

1.1 The grid detail panel

The grid layer allows us to assign a measurement to the image viewer. The size of the grid can be defined in pixels. This is 1-to-1 in the case of images saved at 72dpi. Multiple grids can be used at the same time.

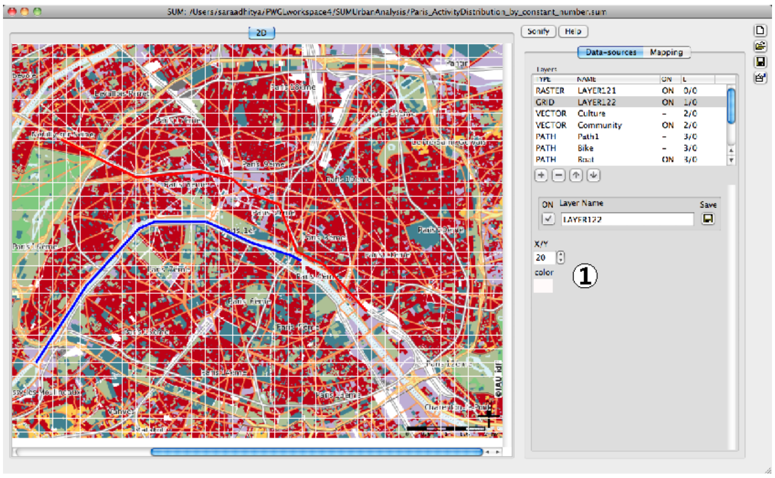


Figure 2: The grid detail panel (1) shows the attributes of the selected grid object

1.2 The path detail panel

The path detail

1. The name of the path, which is used as the reference in the mapping process.
2. The start-time in seconds
3. The speed in m/s or km/h
4. The thickness of the path's appearance. 0 uses the global value which is defined in the user preferences of PWGL.
5. The point type allows the allocation of an image to the animated point of the path in playback mode.
6. The color of the path.

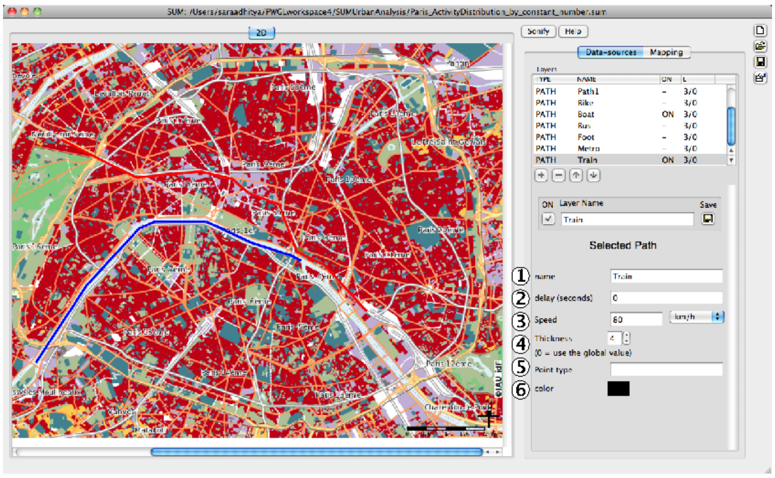


Figure 3: The path detail panel (1) shows the attributes of the selected path object

1.3 The vector detail panel

The vector detail panel allows the creation of new legends or the cloning of existing legends found in other layers. This then allows the color-coding of vector objects created in the same vector layer.

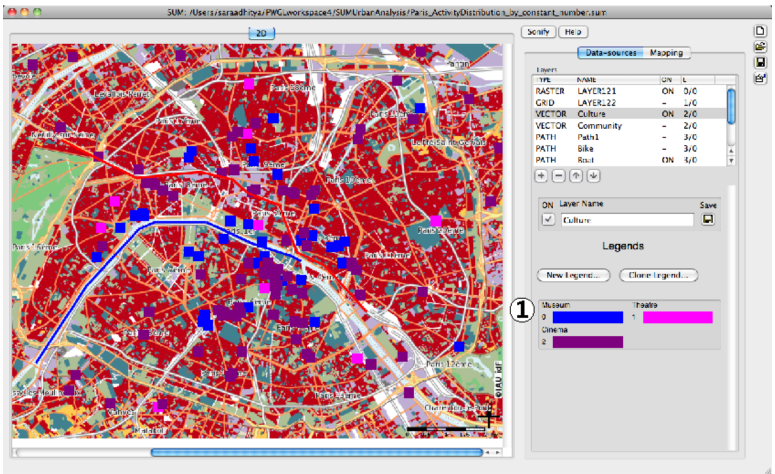


Figure 4: The vector detail panel (1) shows the attributes of the selected vector object

1.4 The Mapping Tab

The Mapping tab is used to define the sonification process. It's GUI will be described further in the Mapping Process section.

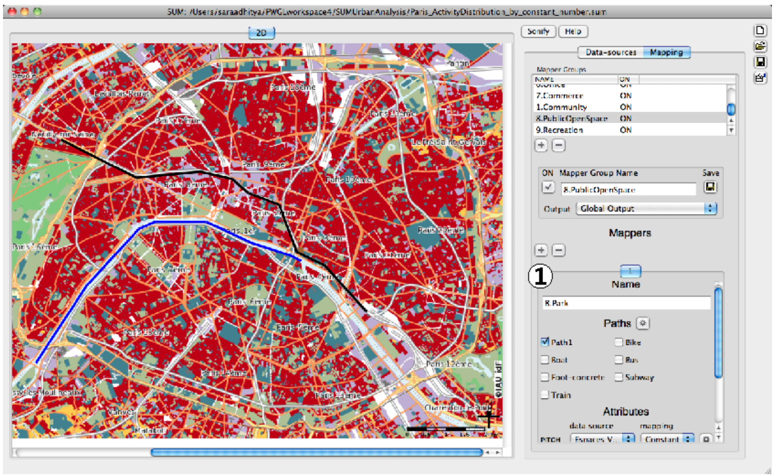


Figure 5: The Mapping Tab (1) shows the attributes of the selected Mapper

2 Internal Structure

The SUM tool consists of three main components: images; paths; and mappers.

2.1 Images

SUM uses images as data-sources. Each image is described by a 'color-key', in which each color of interest is allocated an arbitrary numerical value, to be referenced in the sonification mapping process. SUM supports the superimposition of multiple images, which allows the synthesis of overlapping graphic information, visualisable as a '3D' matrix of data as shown in figure 1. A group of data-sources is called a 'dataset', from which any number of image layers may be drawn upon as data-sources in the mapping process. SUM allows the co-existence of raster and vector images. The flexibility of raster importation permits any visualization, including that produced by other software, to be sonified. The tool's vector drawing ability allows it to be used as a computer-aided design tool, such as Adobe Illustrator or AutoCAD, with graphic changes able to be made internally.

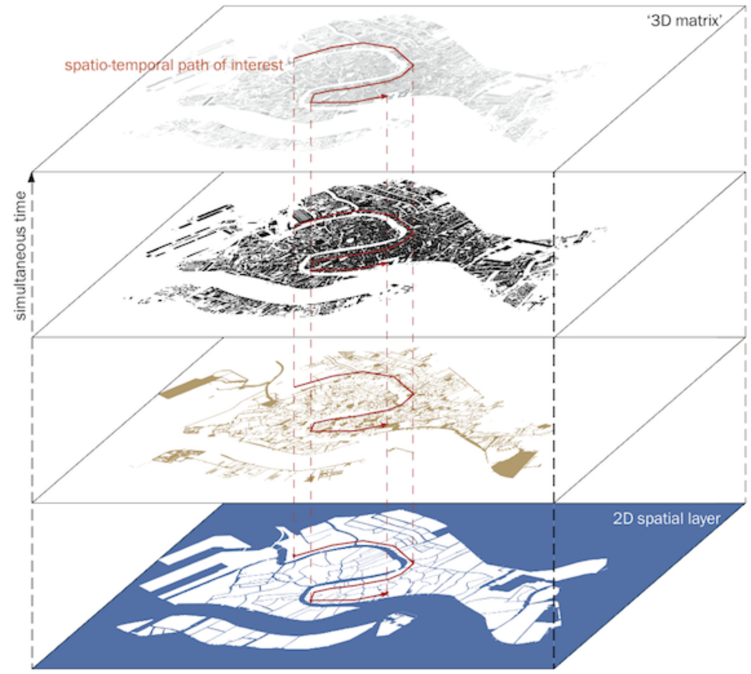


Figure 6: the layers of data form a matrix

2.2 Paths

A path is responsible for defining the connection between the graphic space and musical time. It is a spatio-temporal object consisting of the following qualities: location; direction; delay; duration; and speed. The path is drawn as a vector polyline by the user over the area of interest, and then assigned a speed and delay. SUM supports the co-existence of multiple path layers containing any number of paths.

2.3 Mappers

A mapper is responsible for defining the sound output of the mapping process. It translates the graphic attributes retrieved from the image into discrete audio events, defining the sound attributes of pitch, volume, articulation and timbre. The definition of each sound attribute is independent of another. Thus one mapper can refer to multiple data-sources. A group of mappers is termed a 'mapper-group'.

3 Mapping Process

The SUM mapping process from image to sound is a two-fold process:

1. graphic data is retrieved from a data-source by a path;
2. the data is then applied to a mapper for transformation into audio attributes.

3.1 Data Retrieval

The SUM mapping process is path-driven. Data is retrieved through the drawing of a vector path on an image, and the sampling of the image along this path. The vector path is rasterized according to Bresenham's line algorithm [9] in order to break it down into discrete sampling points, while retaining the order of the points to determine the direction of the path along which the time progresses. Thus for a line extending upwards and to the left, the pixels would be sampled in the order shown in figure 3.

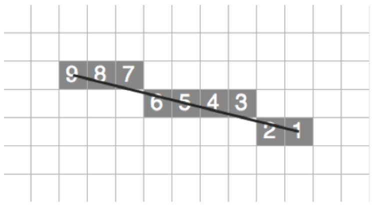


Figure 7: Diagram of Bresenham's line algorithm, with sampling order

Each raster map image is then sampled pixel-by-pixel to retrieve the data of interest per each sample-point along the path. The user-defined start-time and playback speed determines the temporal structure of the mapping process.

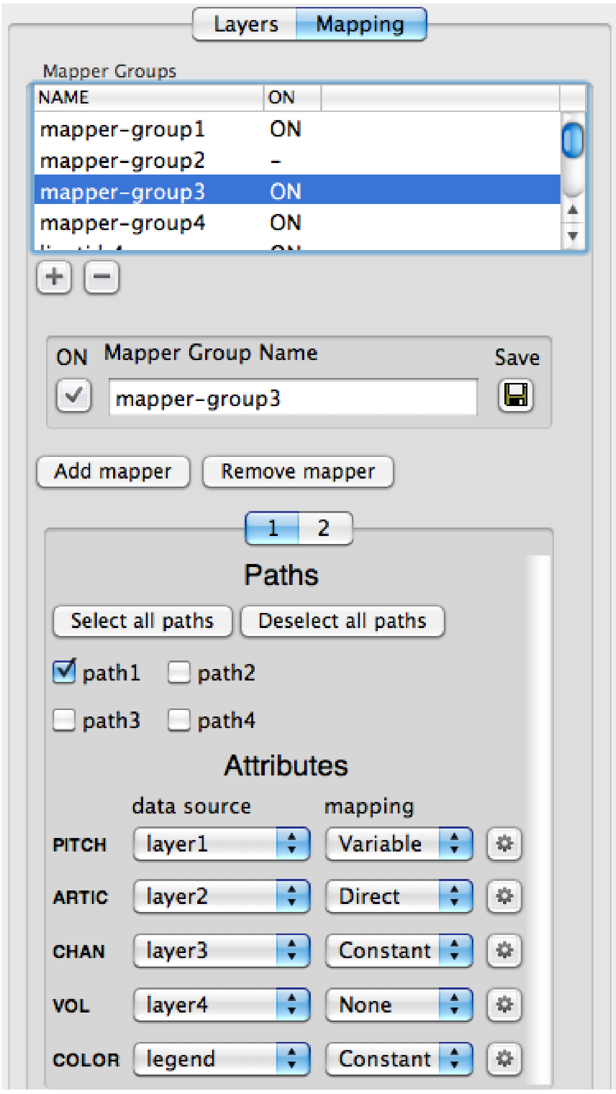
3.2 Parameter Mapping

After retrieval of the graphic information along a path, these values can be applied to a mapper in order to generate the desired sound attributes of an acoustic signal (pitch, volume, articulation, and timbre). The parameter-mapping process is defined by assigning a legend, from a given data-source, with a sound value. This can be implemented either directly through the graphic user interface or by using Lisp for more complicated mappings.

Application of a path to a mapper produces a set of sound parameters, which can then be used to drive a wide-variety of internal or external instruments. PWGL has its own internal synthesizer as well as MIDI and OSC output. This allows connection to external sound synthesis engines such as Max/MSP and flexible possibilities for sound output.

It should be noted that a path and a mapper are independent of each other in terms of data-source/s. Thus different mappings can be generated from the same dataset of data-sources.

3.3 Mapping Options



In the Mapping tab we can define the following mapping options:

1. Naming of Mapper Groups and Mappers
2. Adding and Removing Mapper Groups and Mappers
3. Selection of Paths, per Mapper
4. Selection of Data-source, per sound attribute
5. Selection of Mapping method, per sound attribute

Each sound attribute is defined independently using one of the following 4 mapping methods available:

1. variable
2. direct
3. constant
4. no mapping, in which case the raw value is used

3.3.1 Variable mapping

The variable mapping method allows the definition of more complicated mappings using lisp to define a function. There are two ways of defining the mapping function:

1. (lambda (X) X)

   where X is the legend value to be mapped.

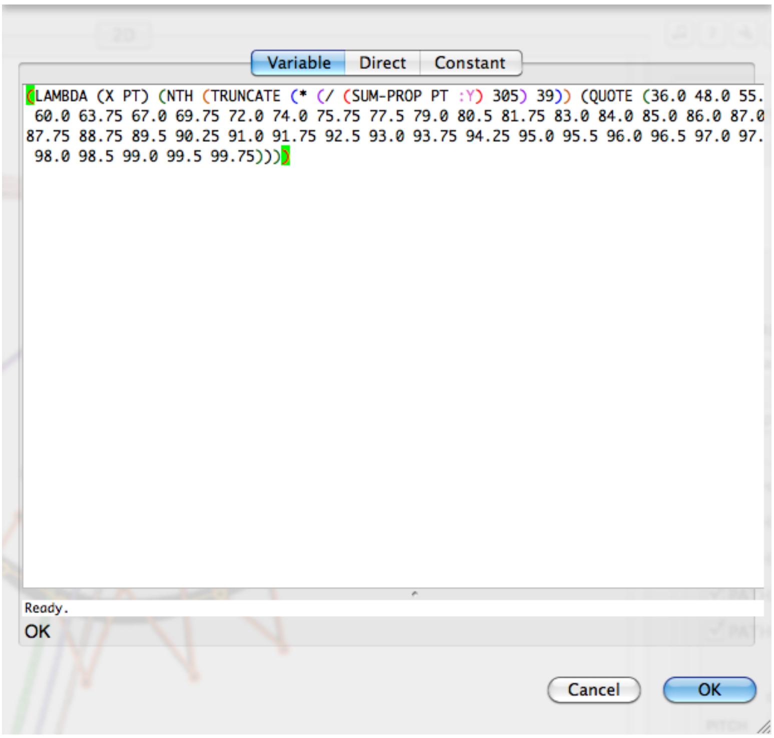
2. (lambda (X) pt) (sum-prop pt :Y))

   where X is as above, and pt is the current point. The properties of the current point can be accessed using a special accessor function 'sum-prop'. The following gives all the signatures of the function:

1. (sum-prop pt :X)
2. (sum-prop pt :Y)

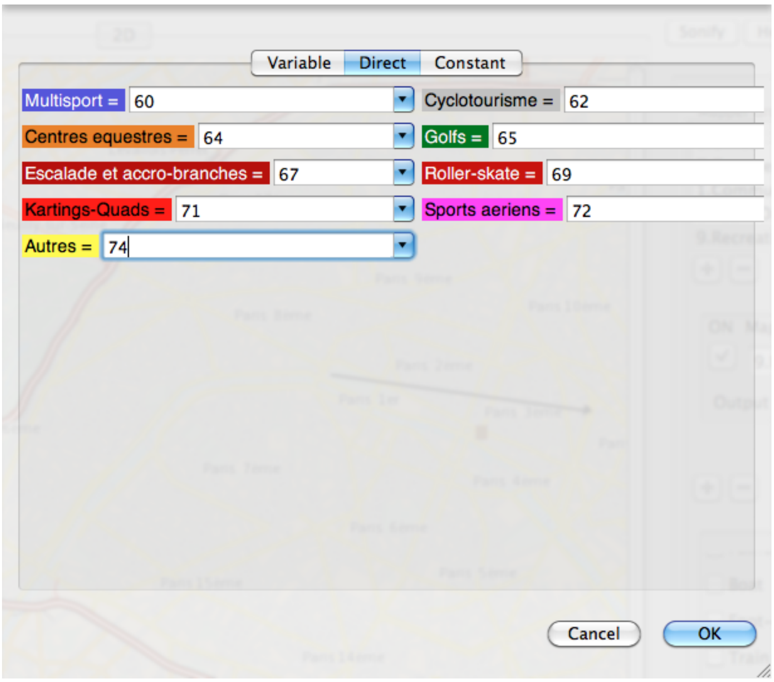
3. (sum-prop pt :TIME)
4. (sum-prop pt :LAYER)
5. (sum-prop pt :COLOR)
6. (sum-prop pt :RAW)

In the figure below, we are mapping the Y value of a point to a harmonic series.



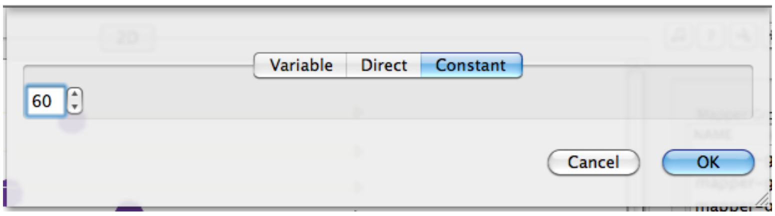
3.3.2 Direct mapping

The direct mapping method allows the mapping of each legend value to a corresponding sound value. Here we are mapping the legend values to the C major scale, in order of appearance and starting from middle C (MIDI note number 60).



3.3.3 Constant mapping

The constant mapping method allows the mapping of all legend values to a common sound value. Here we are mapping all of the legend values to middle C.



3.3.4 No mapping

In the case of no mapping (None) the raw legend values are maintained, starting from 0. This is useful when the values are to be interpreted at a later stage outside of the SUM tool.

4 The SUM Compositional Process

This section will relate the SUM process to the compositional process. Here we introduce the concept of the SUM score, consisting of multiple SUM parts.

A SUM part is a sequence of audio events, the qualities of which are defined by the retrieval of data from an image with a path, and applying this path to a mapper. Thus the generation of a SUM part is a path-driven process. Application of multiple paths to one mapper will produce multiple SUM parts of the same timbral quality, but of variable temporal structure. Application of the same path to multiple mappers will produce multiple SUM parts of the same spatio-temporal quality, but of variable timbral qualities. Different combinations of paths and mappers allow the generation of numerous SUM parts from the same dataset. Figure 1 shows one possible network of paths and mappers producing a SUM score.

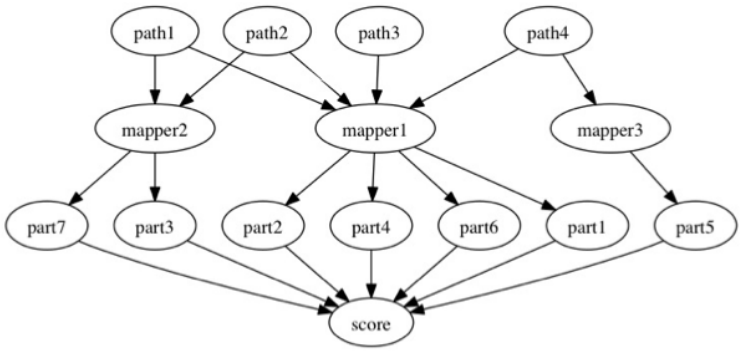


Figure 8: An example of a SUM score - one possible network of paths and mappers

The SUM score can be generated automatically for a particular mapping by selecting the 'generate SUM score' option in the Mapping tab.

5 Appendix 1: Audio Output

The sonification is represented graphically in the form of a color-coded piano roll, which can be generated using the 'Generate' button in the SUM tool window. The ENP score can also be viewed.

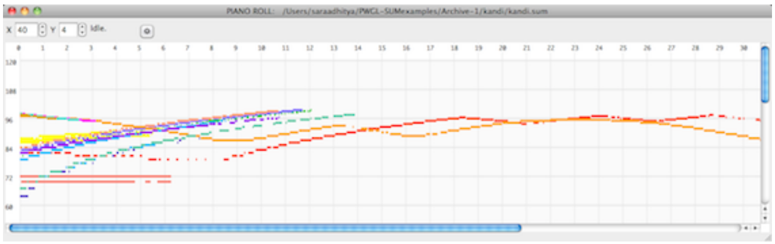


Figure 9: An example of a generated color-coded piano-roll

The piano roll can then be used to control the audio output, using the space bar to start-stop playback. There are 3 types of audio output, which is defined in the Mapping tab:

1. Global
2. MIDI
3. OSC

These allow the generation of audio through the PWGL internal synthesizer, Quicktime MIDI, or an external synthesizer (created for example in MaxMSP or Pd) through OSC output.

There are 2 levels of information detail:

1. Raw (legend) values
2. Mapped (interpreted) values

The OSC output consists of the following name-value pairs:

Name	Data-source Name	Value
/sum_pitch	string	integer
/sum_dur	string	float, in milliseconds
/sum_volume	string	integer
/sum_instrument	string	A user-definable instrument name (string)
/sum_chan	string	integer
/sum_articulation	string	”LEGATO” |”STACCATO”

Name	Value
/pitch	MIDI note number, from 0 to 127
/dur	duration, in milliseconds
/vel	MIDI velocity, from 0 to 127
/instrument	A user-definable instrument name (string)
/chan	MIDI channel number (integer, from 0 to 127)

6 Appendix 2: Mapset Description Language

Raster images can be imported into SUM by using the Mapset Description Language below to create a .mapset file. This .mapset file is then loaded into the tool.

Vector objects are created directly within the SUM tool.

6.1 The Mapset Description Language (.mapset)

```
mapset
 :title "Nedlands, Perth"
   :maps
     :map
       :order 2
       :title "Trees"
       :image "trees.png"
       :legends
         :legend
:data-name "tree"
:data-description :green
:map
       :order 1
 :title "Figure-ground"
       :image "figureground.png"
       :legends
         :legend
```

```
            :data-name "building footprint"
            :data-description :black
```

In the future, raster images will be able to be imported directly into SUM

7 Appendix 3: Keyboard shortcuts

The SUM tool can also be operated using several keyboard shortcuts, relating to the image viewer, path layer and vector layer.

7.1 Image Viewer

Here we can adjust the scale of the image viewer by specifying the degree of zoom via the following commands.

Function	Shortcut
Zoom-in	+
Zoom-out	-
1:1	1
2:1	2
User-definable zoom	u, then type % zoom

7.2 Path layer

The path layer is a container for the vector paths. Paths can be created, selected, duplicated, removed, moved, aligned and manipulated using the following keyboard commands.

Two path states are available:

1. point - for the selection and manipulation of individual points of a polyline

2. polyline - for the selection and moving of the entire polyline

Function	Shortcut
Making a new path	shift a, or double click
Removing a path	shift x
Adding a point to a path	select a point, then type a
Removing a point from a path	x
Defining the coordinates of a point	select a point, then type i
Selecting the next path	tab
Micro-nudging a path	arrow keys
Macro-nudging a path	shift arrow keys
Hide/show points	p
Duplicating a path	d
Aligning multiple paths	= (then choose x or y)

7.3 Vector layer

Within the vector layer, one can create, select and manipulate vector polygon objects.

Function	Shortcut
Create shape	shift s
Select shape	s

8 Preferences: Global Settings

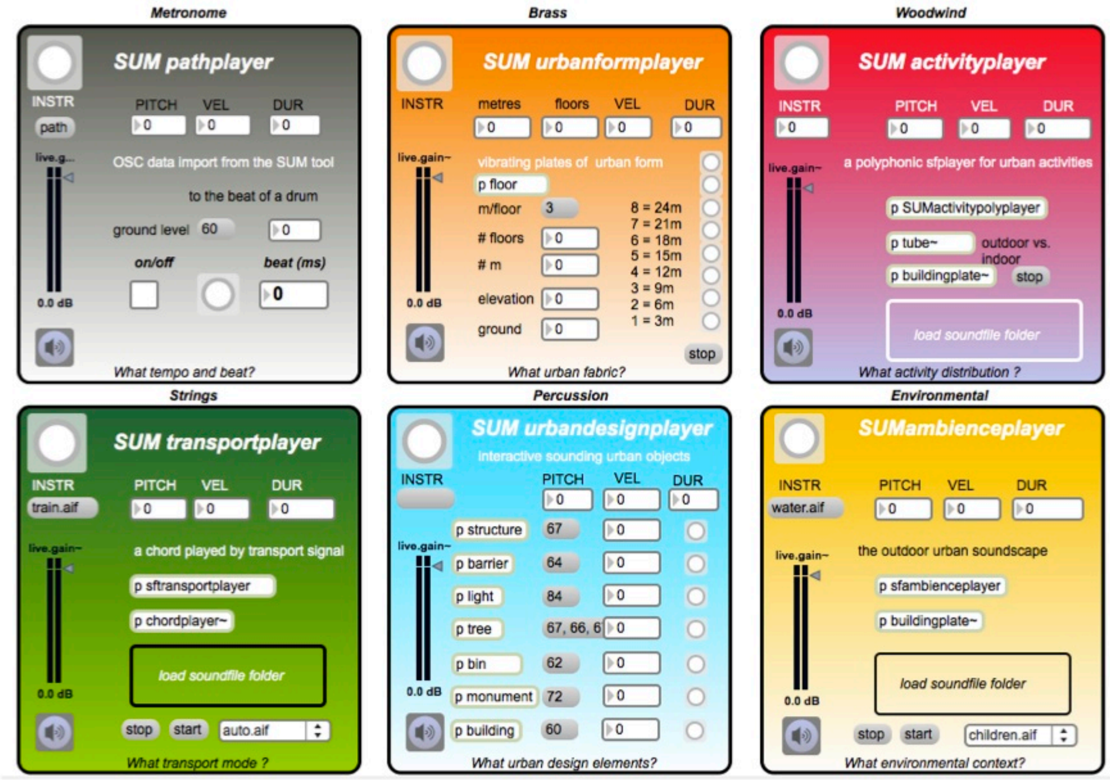
There are several user-definable global settings in the SUM tool, relating to the visual appearance of paths (point-size and line-thickness), the handling of these paths (selection tolerance and path nudging), and the speed of their animation (in seconds). The Audio-output can also be defined in the Mapping tab (see Appendix 1).

Preferences	Definition

Point-size	the size of the points of the path, in pixels
Micro-nudging	the minimum incrementation produced by the arrow keys to move a point or path
Macro-nudging	the maximum incrementation produced by the shift plus arrow keys to move a point or path
Line-thickness	the visual thickness of the path, in pixels
Selection tolerance	the thickness of the 'margin of selection' around objects, in pixels
Animation speed	the calibration of the animated point, in seconds
Audio-output*	MIDI; SYNTH; OSC

Appendix 2:
SUM Urban Instruments

Appendix 2:
SUM Urban Instruments



SUM Implementation

The SUM Urban Instruments have been developed in MaxMSP[1], and are driven by the SUM tool via Open Sound Control (OSC)[2] data import of the following parameters:

- Instrument (as general MIDI, user-defined name or number)
- Pitch, in MIDIcents
- Velocity, in MIDIcents
- Duration, in milliseconds
- Articulation (staccato or legato)

They utilise the Modalys[3] objects developed by Ircam[4], based on physical modelling.

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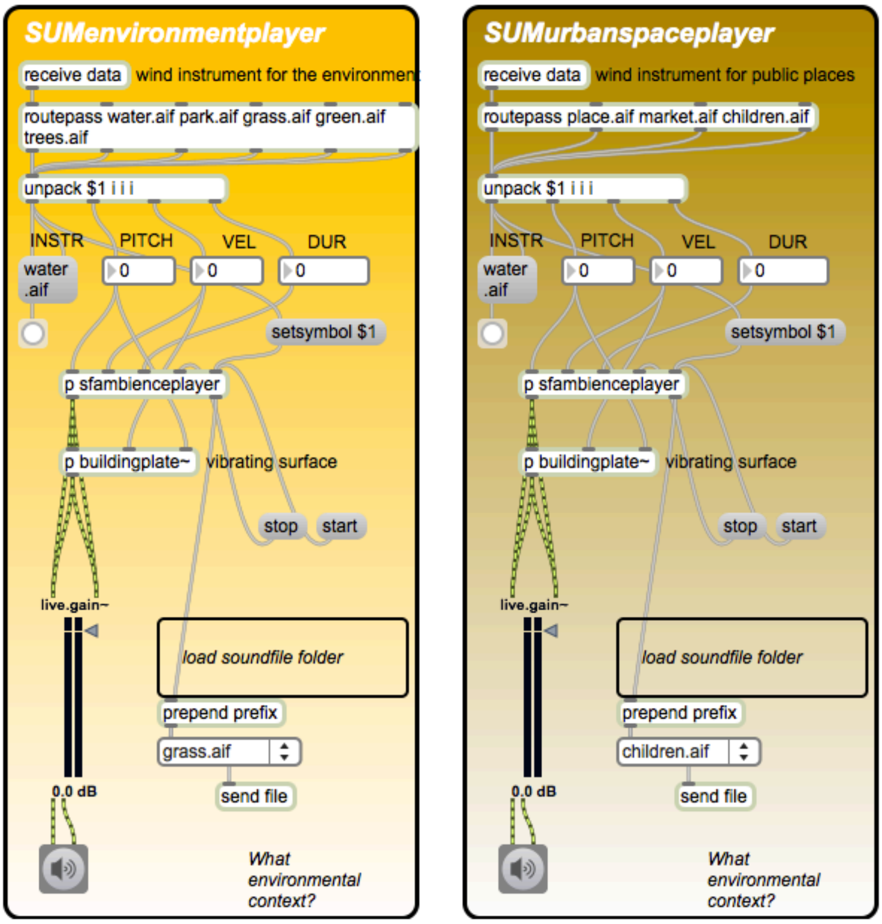
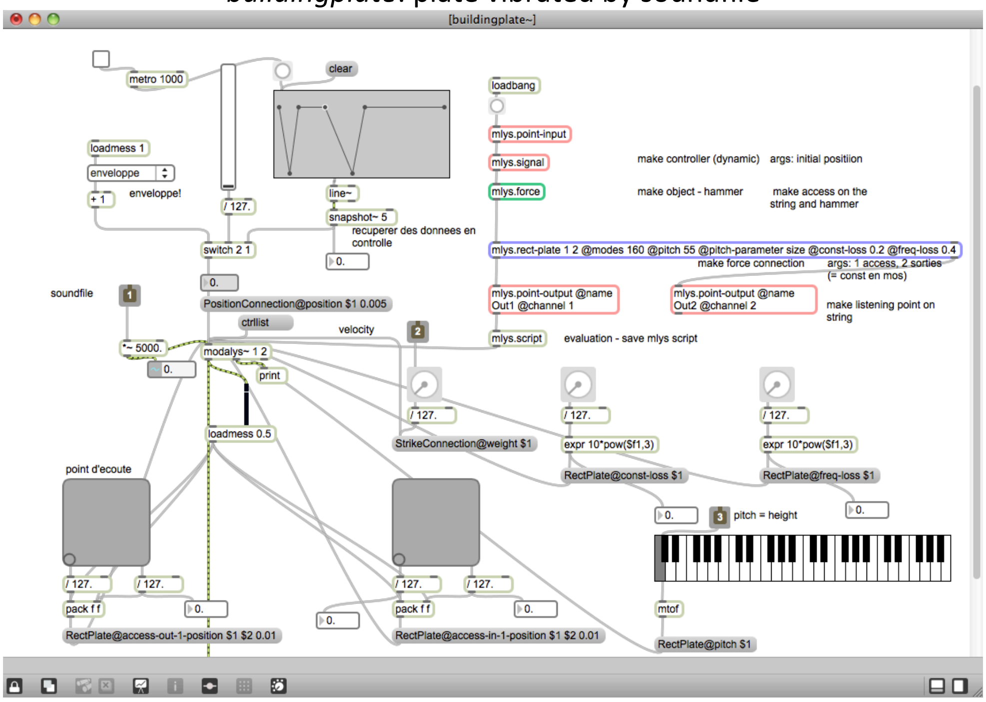
[1] MaxMSP: http://cycling74.com/products/max/
[2] *Open sound control* (OSC), Available from: http://opensoundcontrol.org/introduction-osc
[3] Institut de Recherche et Coordination Acoustique/Musique, Paris
[4] Modalys: http://forumnet.ircam.fr/product/modalys/?lang=en

SUM Environment player

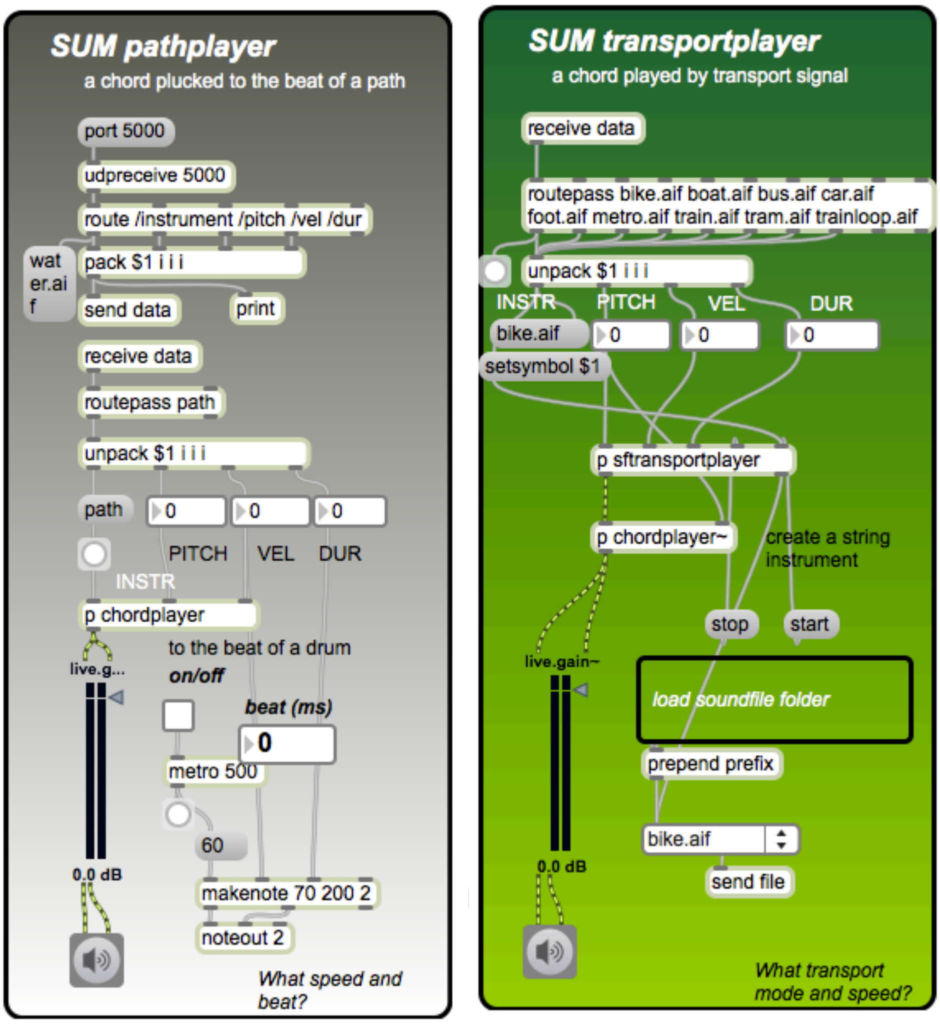


buildingplate: plate vibrated by soundfile

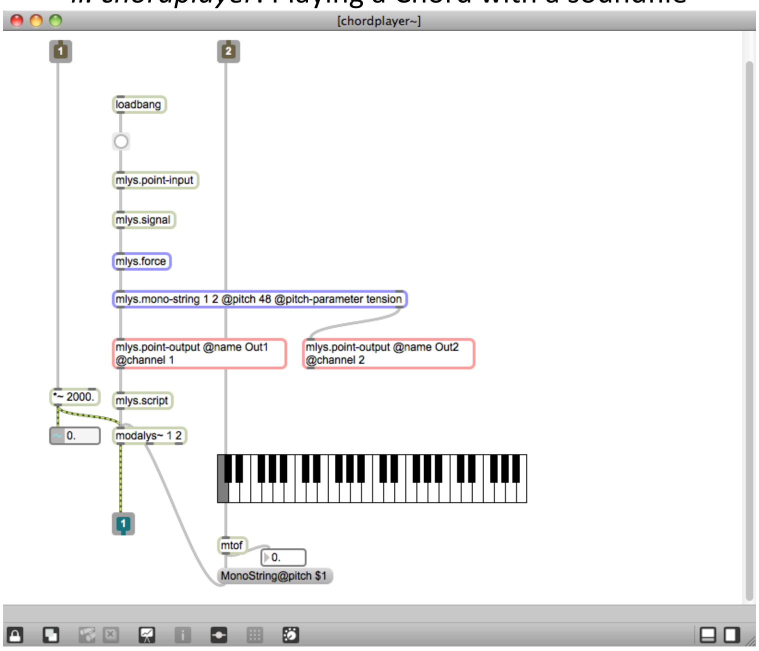


SUM Transport player

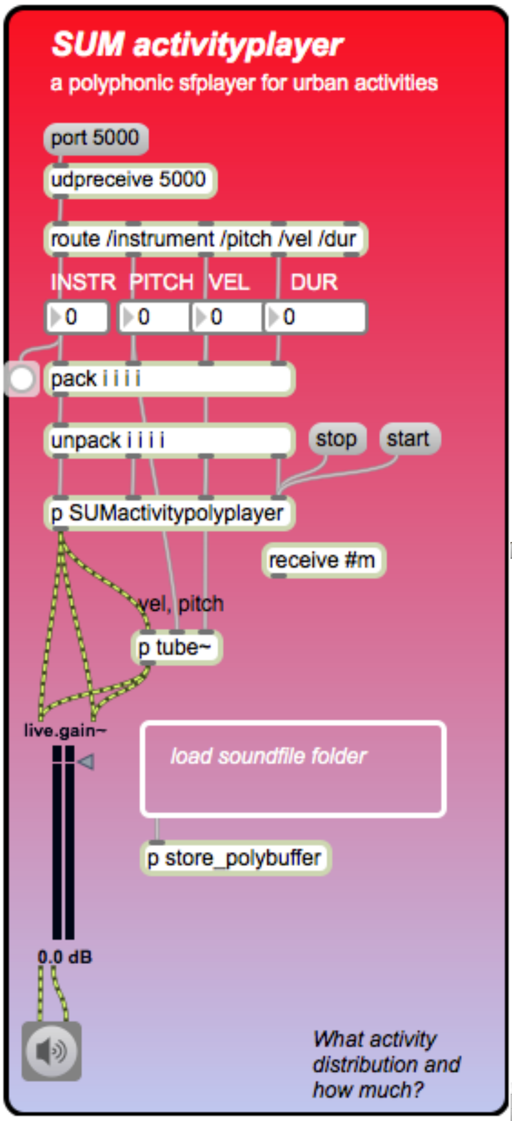
chord played by transport signal



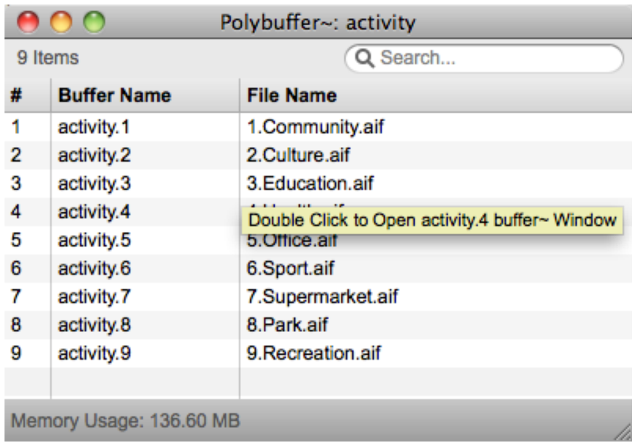
ii. chordplayer: Playing a Chord with a soundfile



SUM Activity player

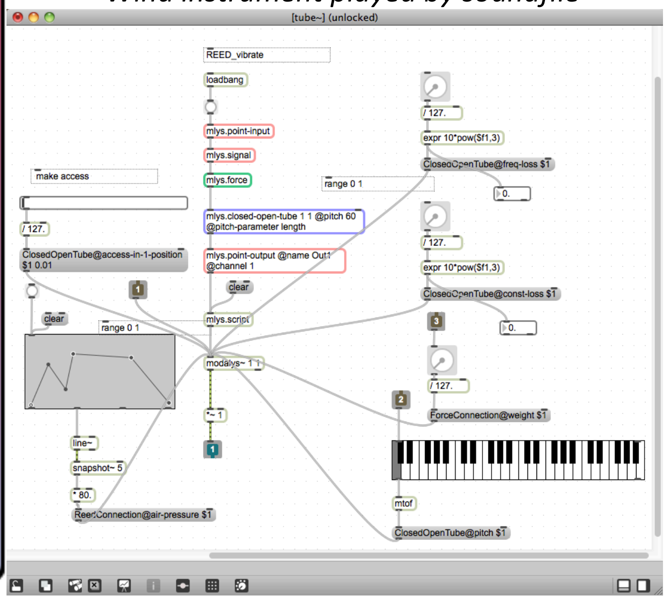


Polybuffer: library of activity soundfiles

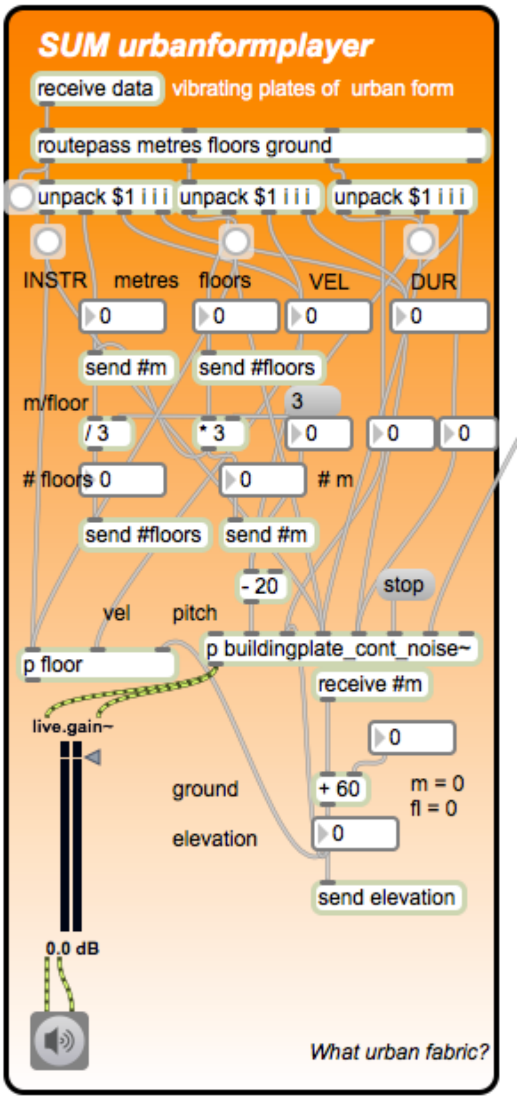


#	Buffer Name	File Name
1	activity.1	1.Community.aif
2	activity.2	2.Culture.aif
3	activity.3	3.Education.aif
4	activity.4	
5	activity.5	5.Office.aif
6	activity.6	6.Sport.aif
7	activity.7	7.Supermarket.aif
8	activity.8	8.Park.aif
9	activity.9	9.Recreation.aif

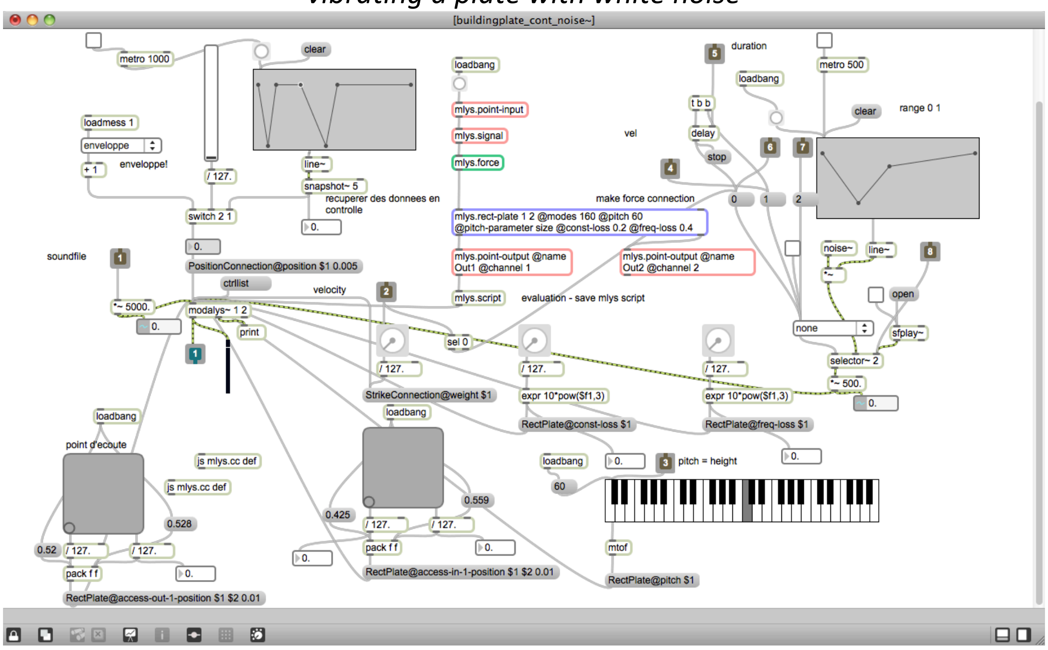
Wind instrument played by soundfile



SUM Urban Form player

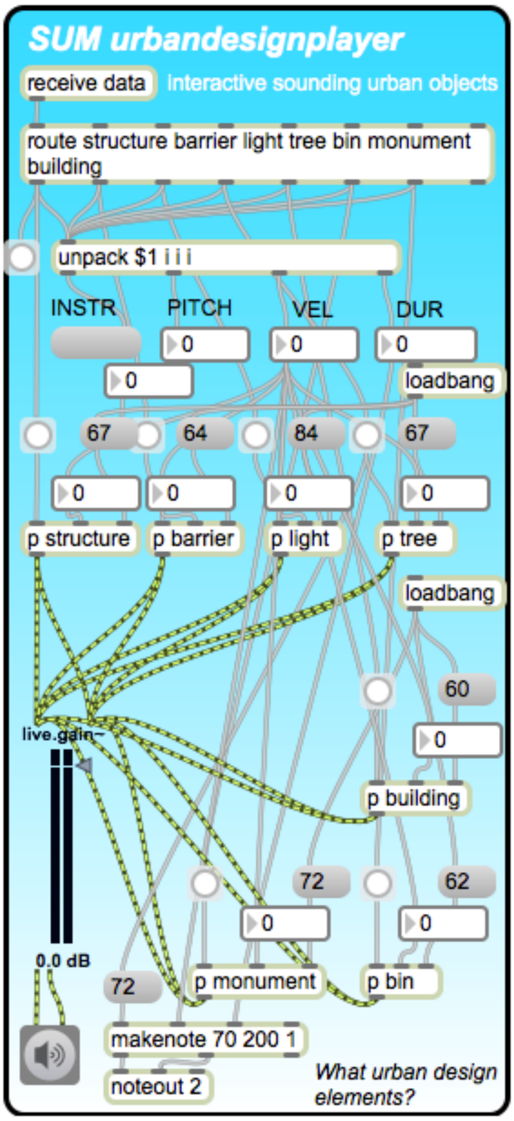


vibrating a plate with white noise



SUM Urban Design player

interactive sounding urban objects



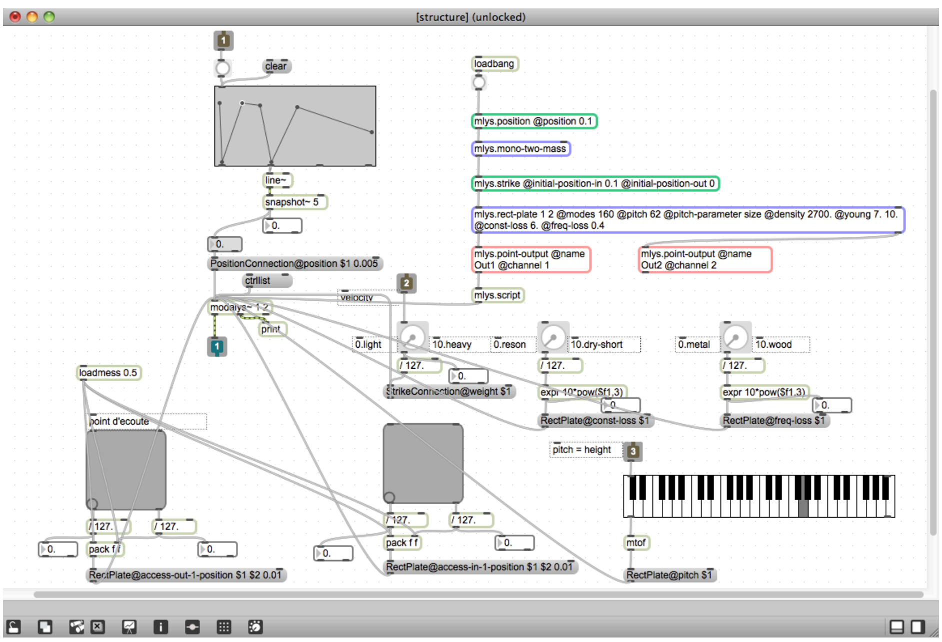
Urban design elements:

- structure;
- barrier;
- light;
- tree;
- bin;
- monument;
- building

Physical parameters

▼ mlys.rect-plate	
access-in-initial-position-x	0.05 0.15
access-in-initial-position-y	0.05 0.15
access-out-initial-position-x	0.1 0.2
access-out-initial-position-y	0.1 0.2
const-loss	0.1
density	8900.
freq-loss	7.
length0	0.5
length1	0.5
modes	160
name	RectPlate
pitch	64.
pitch-parameter	size
poisson	0.3
thickness	0.01
young	1.2 11.

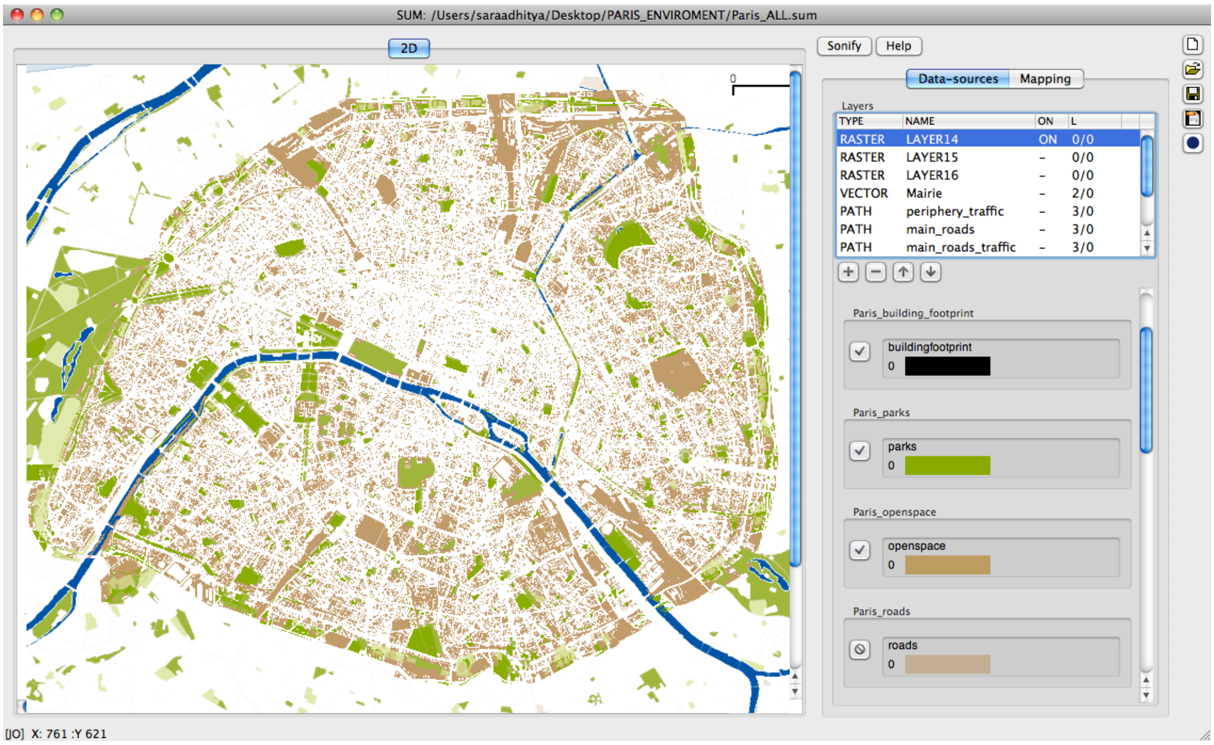
striking a plate



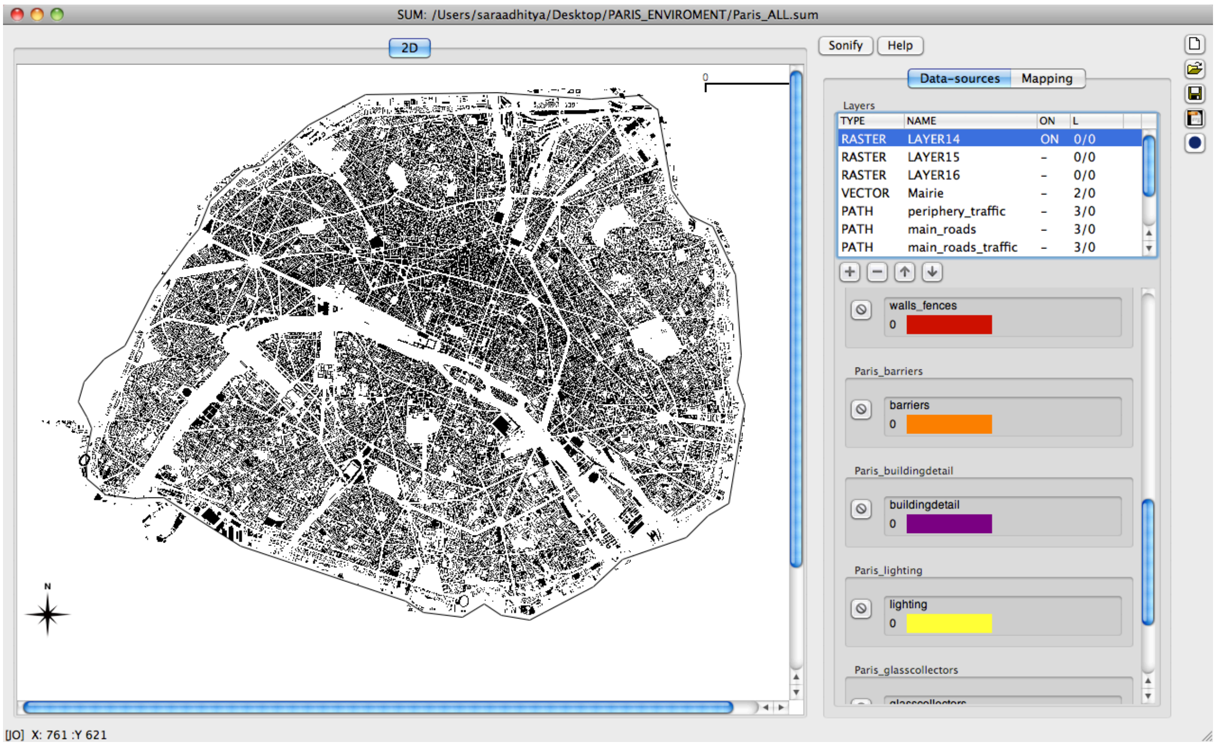
Appendix 3:
SUM Urban Datasets

Appendix 3:
SUM Urban Datasets

SUM Dataset: Natural Environment

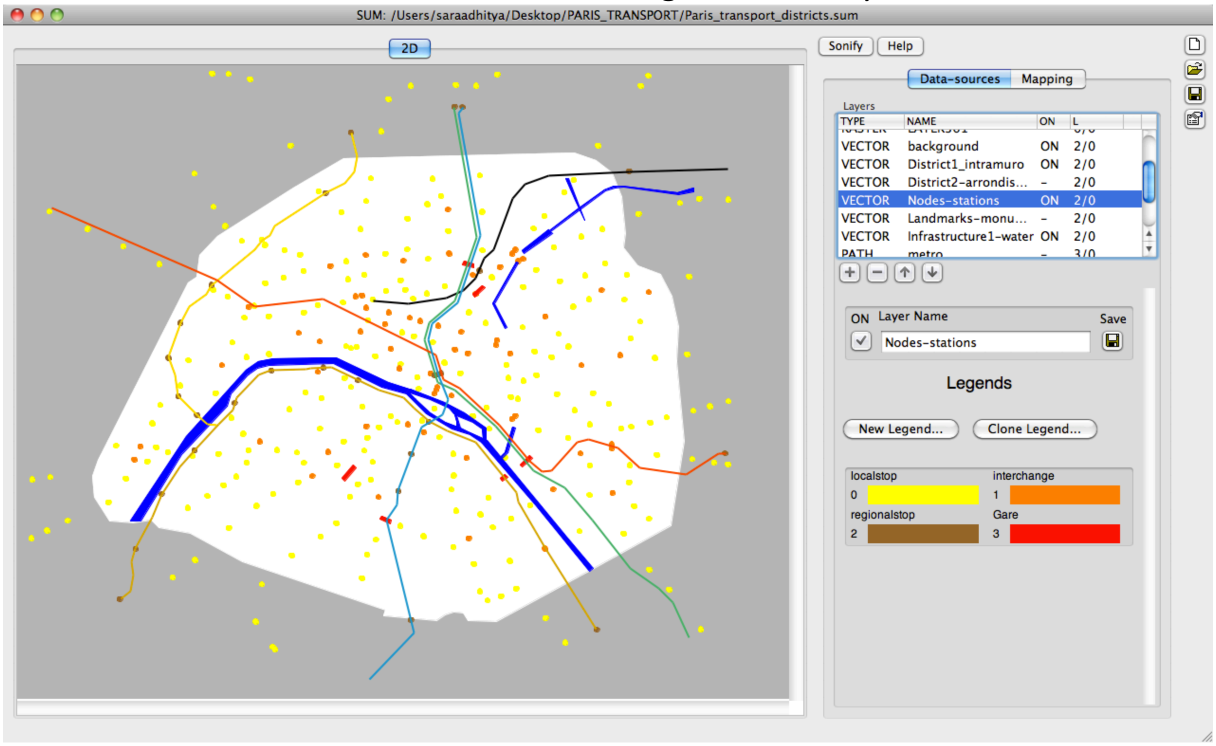


SUM Dataset: Urban Morphology

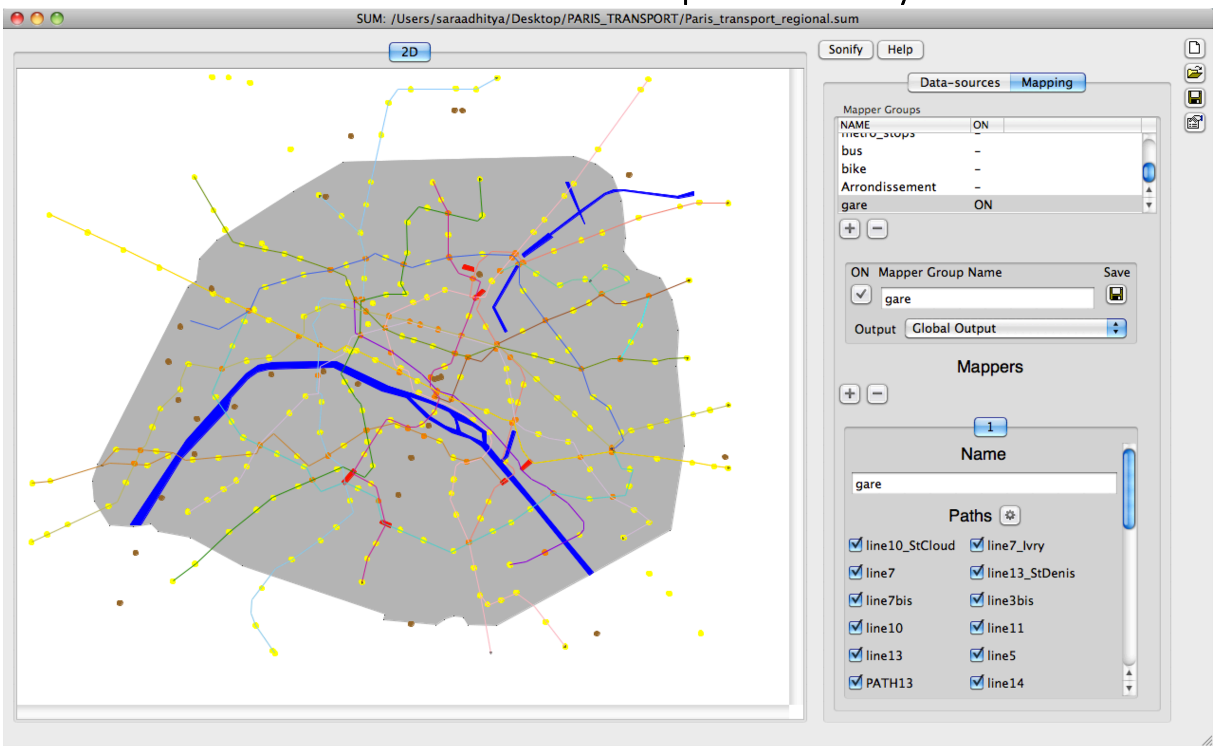


SUM Dataset: Transport Infrastructure

Data-source: Paris Regional Railway

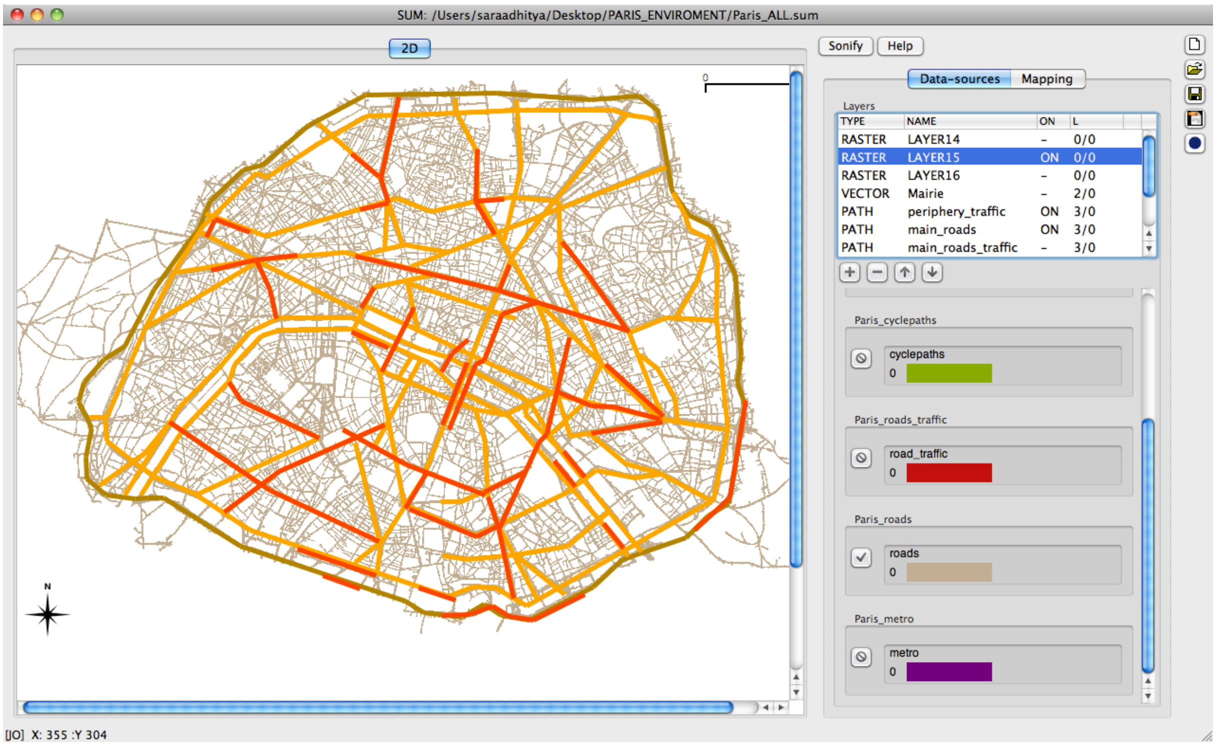


Data-source: Paris Metropolitan Railway

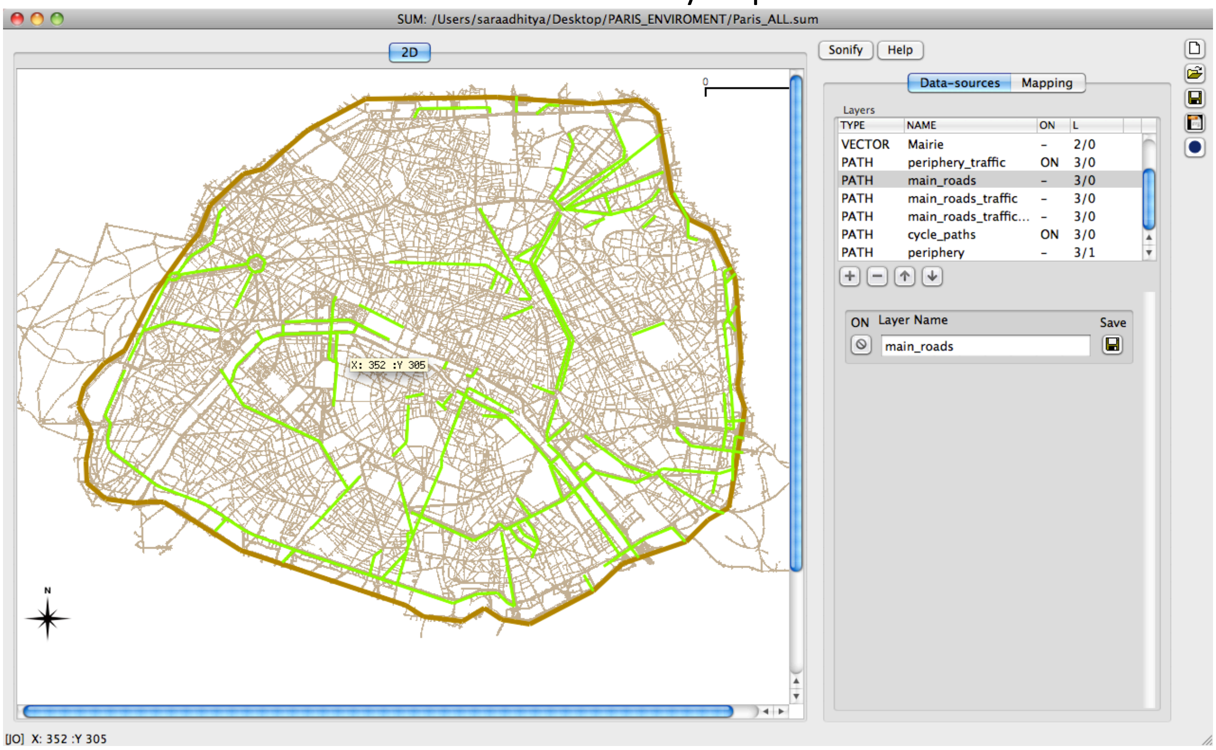


SUM Dataset: Transport Infrastructure

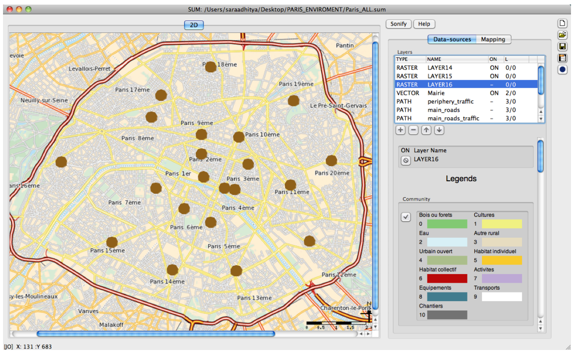
Data-source: Paris Road network



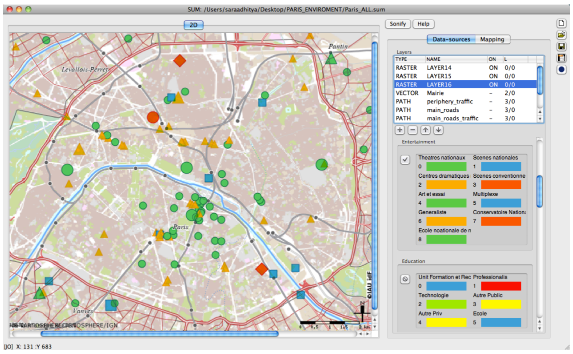
Data-source: Paris Cycle paths



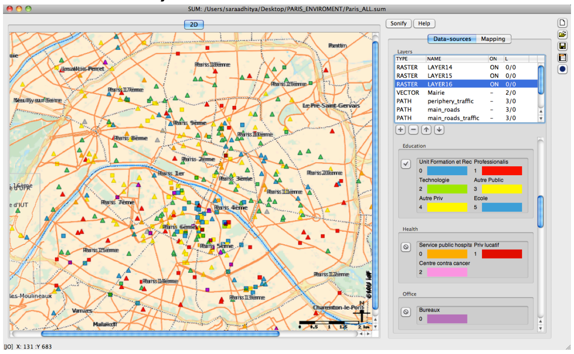
SUM Dataset: Urban Activity



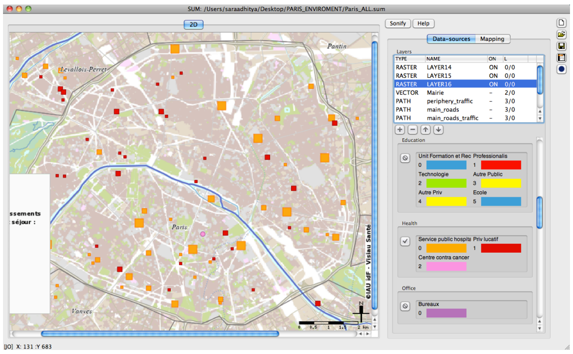
i. Community



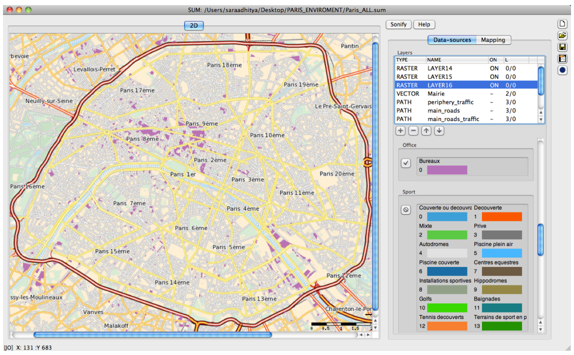
ii. Entertainment



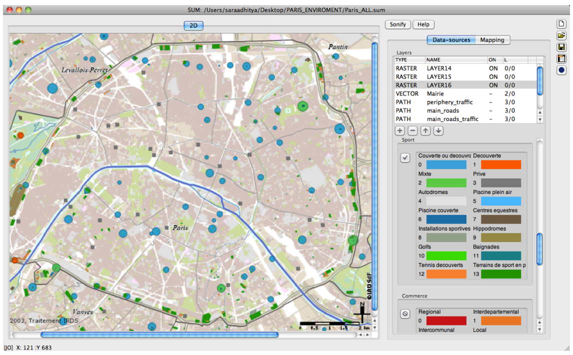
iii. Education



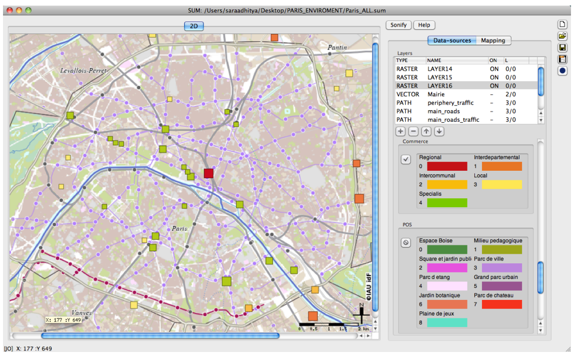
iv. Health



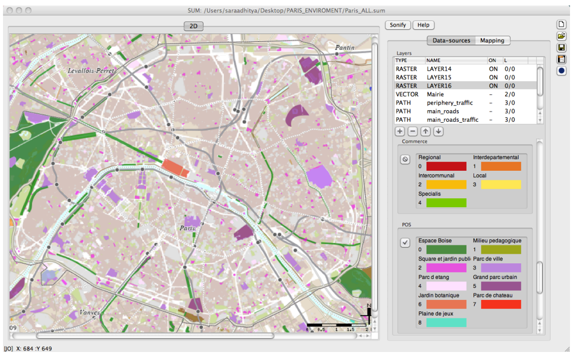
v. Office



vi. Sport



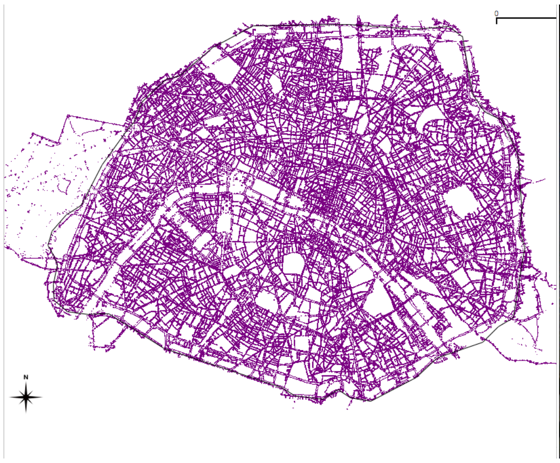
vii. Commerce



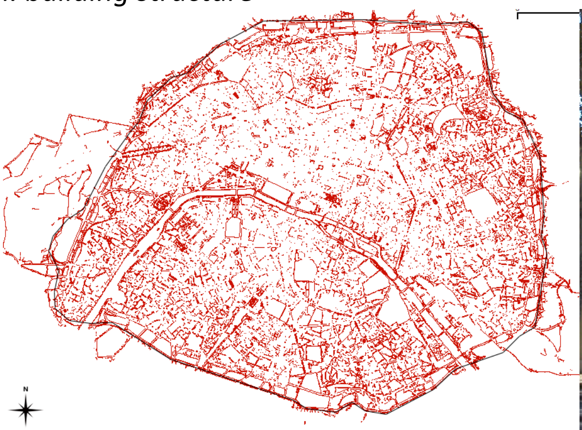
viii. Public space

SUM Dataset: Urban Design

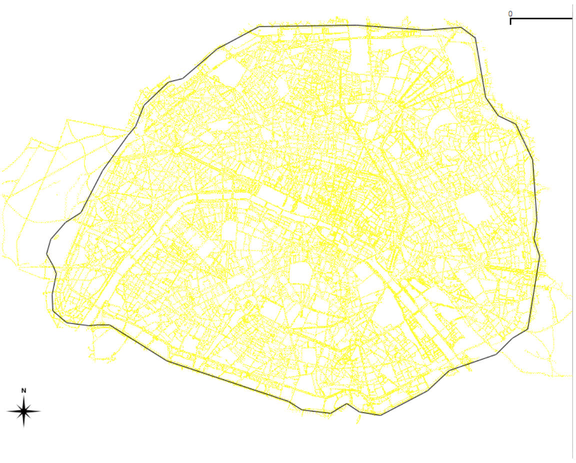
Urban design data-sources: building structure, barriers, lights, bins, trees and monuments.



i. building structure

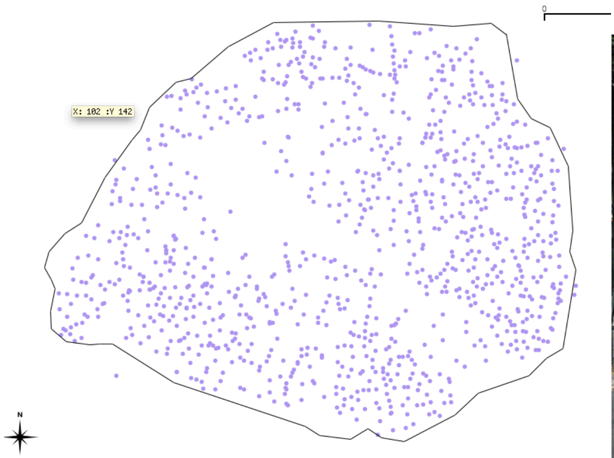


ii. barriers

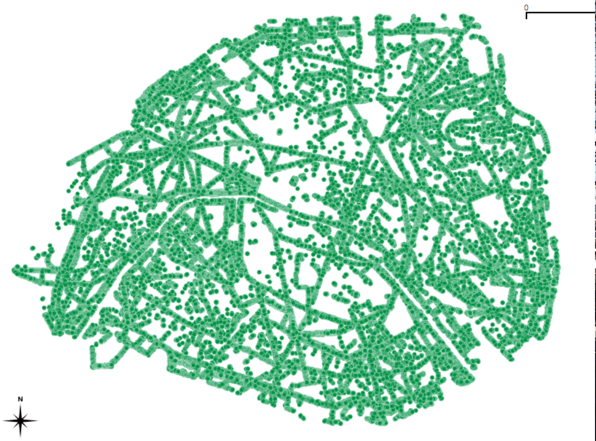


iii. lights

SUM Dataset: Urban Design



iv. bins



v. trees

vi. monuments

Appendix 4: Questionnaires & Experiments

Appendix 4:
Questionnaires & Experiments

I. Questionnaire 1: SUM as a representation tool

- Responses from the general public

II. Questionnaire 2: Urban Space-Time-use Survey

- Responses from 'Rhythmanalysis' participants

III. Listening Experiment 1: Sonified Daily Urban Rhythm

- **Listening Exercise 1: Urban Sonic Code**
  i. Video 1:
  https://www.dropbox.com/s/3y1w0z65kaznexi/SUM_survey_UrbanSonicCode.mp4
  ii. Questionnaire 1*: Urban Sonic Code*
  http://www.surveymonkey.com/s/D65GBSR
  iii. Video 2:
  https://www.dropbox.com/s/02ztbk6fetpf8f8/SUM_survey_ListeningExercise1.mp4

- **Listening Experiment Part 1: Your Sonified Daily Urban (SDU) Rhythm**
  iv. Video 3:
  v. Questionnaire 2A : *Your Daily SUM Rhythm*
  http://www.surveymonkey.com/s/98N68MM

- **Listening Experiment Part 2: Identifying your SDU rhythm**
  vi. Video 4:
  https://www.dropbox.com/s/0zywo4xwwtbofml/SUM_survey1_sonifications.mp4
  vii. Questionnaire 2B*: Identifying your daily SUM rhythm*
  http://www.surveymonkey.com/s/7DL3WZZ

IV. Questionnaire 3: SUM as a design tool

- Responses from urban professionals

I. Questionnaire 1: SUM as a Representation Tool

Participants: General public (not including architects, urban designers or planners)

1. What were your initial impressions of SUM?
2. What sort of aesthetic or emotional response did SUM provoke?
3. What aspects of the city did SUM reveal to you that the graphic plan could not?
4. How did SUM increase your awareness of the different rhythms in the city?
5. How could SUM further enhance your experience?

Questionnaire 1: SUM as a Representation Tool

1. **What were your initial impressions of SUM?**

i. I found it to be very interesting, both artistically and from a more practical point of view. The sonified elements really complement the image by intuitively providing an overall feel of the area while also being an interestingly pleasing musical experience.

ii. My first impressions were wow, what a really interesting and novel approach to display and interpret urban design and use. I particularly liked the use of the multimedia sequences to layer the various urban features over the mapping and sound. I recognised how this would be so very useful in other applications, like offices and hospitals and where the 'human' response to plans would be so much more real.

iii. Initially guidance and orientation in the map still seemed to depend on visual representation, which slowly became less importand for understanding the journey

iv. SUM is a clever way to describe or survey the city in a non-verbal manner. From viewing just the output, it appears to be simple to use and a nice tool.

v. I found it a little confusing at time, but the final screen drew all the points together and it made sense. I'm not sure where the sounds for each feature come from - are these arbitrarily composed/designed by SUM or the user?

vi. The abstract concept becomes more clear when we see a visual representation of how the elements of an urban environment are layered over each other.

vii. It's an interesting and beautiful addition to a regular map. I felt a bit overwhelmed though as I wasn't sure whether this is intended as a solely sonified map or as an addition to a graphic. I could very well imaging this as an addition, but I think it would require too much learning if it's intended as audio-only.

viii. For the musicologist that I am, it's unexpected and very interesting. I can not help but listen to the sounds for themselves (as we learned Pierre Schaeffer with "reduced listening"). At the same time, I understand the logic of sonication and I think that the whole is successful.[1]

ix. I thought it was interesting to see how your environment could have an impact on you without you even knowing. It is also interesting to learn about a new way to compose music.

x. Unusual but very interesting idea.

xi. It is very curious, so very interesting: it provokes a lot of questions.

---

[1] *Pour le musicologue que je suis, c'est inattendu et très intéressant. Je ne peux pas m'empêcher d'écouter les sons pour eux-mêmes (comme nous a appris Pierre Schaeffer avec l'"écoute réduite"). En même temps, je comprends la logique de la sonification et je pense que l'ensemble est réussi.*

xii. I was not sure what would be presented. From the title, I presumed I would be given a new set of tools, a new way of looking, of thinking about, an urban environment.

xiii. Surprising, revealing.[2]

xiv. Overall I like the sounds very much, from an aesthetic perspective. Analytically speaking, though, the mappings between sounds and meaning were not completely clear to me. There seems to be a mix of iconic/representational samples and synthetic/abstract sounds, and I'm not sure about the rationale of the choices there (which is used where, and why). Overall the representational samples were easy to identify, but the synthetic sounds less so. They seemed to change in some respects with the content but also remained mostly the same (including pitch, timbre, etc...). So overall an impression of beauty and mystery, but also a mild frustration due to the fact that my rational and pragmatic mind could not understand it all.

xv. It is very unusual to think of the city as a system of sounds.

xvi. Interesting - want to try it myself. Can we sonify other things than paths? Regions or streets? Can I control the points myself?

xvii. Very intriguing concept and good overall execution / application

xviii. I liked the mappings between urban structures and sounds but also the way they were all combined together. The final result is quite pleasant and informative. Of course, some mappings are easier to interpret with no training, while for others I would need some more experience.

xix. I was impressed by the variety of featured transport systems, environments, and corresponding sound elements.

xx. One can easily assimilate the visual data presented as (s)he follows the structured relationships between them!

xxi. A very ambitious project, capable of triggering powerful emotions. I am still a bit confused about some details.

xxii. Initially, fragmented and a bit confused, but this changed as the video progressed.

xxiii. Curiosity, interest

xxiv. interesting experiment to experience a city

xxv. beautifully detailed graphics layering, interesting sounds demo video didn't allow to check if sound classes can be distinguished and to really understand the mapping in the sonification

---

[2] *Sorprendente, rivelatore*

2. What sort of aesthetic or emotional response did SUM provoke?

i. It was a very pleasing experience, like listening to a piece of music. Reminded me a lot of ambient electronica music, but being actively linked to the environment instead of just being used to complement it in some way.

ii. The emotional response was the strongest – this was because I could recognise Paris to my own city very easily. I almost immediately understood the multimedia presentation and could see how powerful soundscapes can be in urban planning. When I consider my own experiences cycling through Perth, it was a real contrast- we have a wonderful bike path that follows the river BUT is adjacent to a major freeway – the soundscape is horrid! Also without ever visiting Paris, I felt that I could understand how the morphology had shaped use – and the slide in the middle of the presentation helped explained how form dictated function in an old city

iii. Recognition, especially in the biking itinary. It also caused reflection of possibilities for applications.

iv. SUM provoked pleasant emotions with pleasant sounds. Looking at the map and listening to the music simultaneously provoked visualisation of the journey. I tried to imagine the emotional component of a particular journey based on its sounds and the elements they represented. I felt curious about other journeys, including my own.

v. Confusement, intrigue, city has some life to it

vi. At first, slight confusion. I wasn't sure what dictated which sounds. I found some sounds made sense (education: children/background noise, etc), but others evoked a less pleasant response (movement down Haussman to Concorde, at 1:02). The high pitched sound created an emotion of (almost) anxiety. (Maybe on purpose, as its a highly congested area?)

vii. It's a much deeper experience than just looking at a map. As the examples in the video are about places I've been to, I feel transported there and biking down Boulevard de Sebastopol but in a more aware fashion than I would normally do.

viii. At this point, I think it is difficult to talk about aesthetics or emotion. I think the word "interesting" would be more appropriate. [3]

ix. I would say that the images connected with sounds provoke interest and makes me want to learn more about the project.

x. Amazing aesthetic result; it is a musical composition.

---

[3] *A ce stade, je crois qu'il est difficile de parler d'esthétique ou d'émotion. Je pense que le mot "intéressant" serait plus adéquat.*

xi. It provoked intellectual response: that means that it stimulated my desire of knowing the city in a new way, but not directly my aesthetic or emotional sides.

xii. The summary boulevard de Sebastopol, and the initial boulevard used at the start, with the moving dots, and the resultant music, provoked a big grin on my face! It made me very happy.

xiii. The curiosity to understand more routes and more cities with the same sonic legend.[4]

xiv. As said above, there is some beauty to the sounds and the way they complement the images. The video is nicely edited.

xv. It is very intense and sometimes makes one feel suffocated by the density of activities.

xvi. Fun, couriousity (sound and visualization was not always synchronized)

xvii. emotional: -I lived in the area for 6 years and the analysis of Bld Sebastopol feels very familiar - many of the sounds evoke emotional feelings as they mimic the real sound

xviii. Not easy to describe. The result was rather pleasant. I particularly liked the transitions from neighborhood to neighborhood. Arriving at streets with parks, water and markets was very satisfying. In contrast, walking in common streets was a bit monotonous.

xix. For me, it was less a question of conveying an identifiable aesthetic, and more the pleasant, non-irritating qualities of the visuals and audio.

xx. Lively, natural and almost playful data representation. Boulevard Sevastopol by bike sounds gooood :)

xxi. It provided me with a charming and unusual image of the city, increasing my desire to enjoy more the sounds all around the places that I visit.

xxii. Intrigue and a sense of calm!

xxiii. Surprise

xxiv. friendliness, makes me curious what will come next while exploring a city

xxv. interestingly modulated sounds, a bit monotonous in the single examples, but coming nicely together in the final example

[4] *La curiosità di interpretare più percorsi e più città con la stessa leggenda di suoni.*

3. **What aspects of the city did SUM reveal to you that the graphic plan could not?**

i. It gives more of a feel of the area represented than a regular map would. How dense and busy the area is, what can be found in each part of the city, etc..

ii. How sound is part of the form and function of an urban space.

iii. Some emotional aspects of being in the crowd an image can not represent adequatly. Most importantly, movement was represented well.

iv. It is a different way of expressing and analysing the rhythms of the city. There was another creative element/layer, i.e. assigning different sounds to different aspects of the city.

v. The intersection of graphical features (e.g. streets, buildings, etc), urban design, and movement through the environment.

vi. Made me think about other layers/activities/elements in the urban environment that one may choose to ignore or accidentally tune out. For example, Community, Public Space, Lighting, Trees, Parks, Monuments. All of these add extra layers that can be pleasant auditory addition to the urban experience.

vii. I think SUM allows to perceive the city without having to explicitly parse a map. Assuming that all the information layers that are used in SUM were displayed on a graphic map, it would be very dense and require frequent references to the legend. With SUM I get a multiplexed impression that is bound to a certain pace - in the example the pace of riding a bike. The pre-set pace also allows me to have an idea of distances. With a purely graphic map it is often hard to judge how long it would actually take me to walk or bike from one place to another - especially for an unfamiliar city.

viii. SUM reveals the extraordinary plurality of the city. When walking through a city, either we are unaware of its various aspects, either we observe them one to one. When we look at a simple plan, it is flat, uniform, and does not reveal the plurality. With the sonic polyphony of SUM, we see immediately that plurality.[5]

ix. It gives another dimension to where we live and makes us think about our environment. I reflects the small details of a city that a simple graphic cannot. It also gives life to the city, showing how the city is being used by its inhabitants.

x. I believe it informs you in a more accurate way of what exists in an area. While visually you can only focus on one thing, aurally you can have more than one input. Thus, with SUM you are better informed about what you can find in a neighbourhood, and what "types" of neighbourhoods there are around the city.

---

[5] *SUM révèle l'extraordinaire pluralité de la ville. Lorsqu'on traverse une ville à pied, soit on est insensible à ses divers aspects, soit en les observe un à un. Lorsqu'on regarde un simple plan, il est plat, uniforme, et ne révèle pas la pluralité. Avec la polyphonie sonore de SUM, on s'aperçoit tout de suite de cette pluralité.*

xi. First of all the third dimension, but the forth and the fifth as well: people and their possible experience era there. It revels a possible link between the urban and the social system.

xii. The distribution of trees and bins, are not typically available through a traditional graphic plan!

xiii. An element more dynamic in time and more creative in the interpretation of the space around me.[6]

xiv. It emphasized the importance and ubiquity of sounds in a city, something that we easily forget about when we watch a silent map. It made me more aware of it. Maybe I felt more "immersed" when I was watching this "cursor" (metro or walking person?) move along the street.

xv. SUM reveals the diversity of the city and the panel of activities, infrastructures and ambiances the city boasts.

xvi. The impression of creating and feeling paths through the city, whereas a plan is not linear.

xvii. graphical plans are either looking at one single aspect (e.g. the trees, the metro stations, etc) or when they put everything together it becomes very noisy and impossible to communicate with. This is why most maps only concentrate on what is important (e.g. roadmaps give details of roads, tourist maps details of tourist sights and less details of roads, etc). SUM helps to enrich the map (graphical) experience with a powerful additional dimension - the sound. I could imaging the SUM could work really well for estate agents to communicate much better around characteristics of neighborhoods . That could be also done by a touch panel approach where you look at the city, zoom in with your hands and where you then touch you get the SUM of that area.

xviii. The fact that the city is alive, that there are things that happen and change, that walking in a street you can see many different things from one square to the other and discover things.

xix. Local visual/visuo-spatial density, repetition, and variation. Essentially, differences in temporal experience that are typically not conveyed visually.

xx. Life! Interaction and evolution.

xxi. The life in the city, the inhabitants and their routines, the intrinsic expressiveness of living together as part of a whole.

---

[6] *Un aspetto più dinamico nel tempo e più creativo nell'interpretazione dello spazio intorno a me.*

xxii. It was more experiential than just looking at a graphical plan, gave me a sense of timing of a place in a similar way to physical travel.

xxiii. The way different sounds can come together and form a music, rather than just noise, and the way that this can describe something graphic and static

xxiv. emotion and the feel of time by analyzing a city

xxv. regularity/irregularity of features immediate tagging of semantics (by very literal sounds), whereas the mapping from a colour legend in a plan to meaning has to be looked up first

4. **How did SUM increase your awareness of the different rhythms in the city?**

i. SUM made it very easy to see which parts of the city have a more intense rhythm. It also showed how each part of the city is characterized (i.e., which have more parks and open spaces, etc.).

ii. Yes, and it was really powerful – this model could be used for so many different applications especially in mufti-function buildings like schools and workshops. It really helped understand how the natural terrain and its sound environment can be altered, and how I could choose to travel via a route that is audibly pleasing.

iii. As a biker i did have some awareness that fitted well to the rythms represented in the video, as movement and multiplicity (different layers) could be experienced as a composition

iv. It allowed me to hear the frequency of certain facilities, and compare them aurally. I thought the different volumes for different traffic patterns was helpful in making the user aware of their experience of those patterns from a distanced perspective.

v. It enabled a sense of movement through the city and gave a depth to the experience as the different layers (rhythms) revealed themselves.

vi. The multiple layers (and thereby rhythms) possible in one geographic location.

vii. In the video there is only one real example for a bike ride. It allows me to get an idea of different rhythms for different activities within the city. However, I think that the perception of rhythms changes with the speed by which I move through the city. It would thus be interesting to hear more different examples when using different modes of transportation.

viii. For now, I find it hard to answer this question [7]

ix. I was surprised by the number of sounds that one can find in a city and how each small structure and activity has a sound.

x. By the complexity of the resulting compositions. It is really impressive to realise how many different things are going on at the same time.

xi. It puts systematically together many aspects of the urban environment to which you normally don't pay attention. So you can see in which "rhythms's web" you live and move.

xii. By showing different aspects of a physical environment separately, such as water, open spaces etc., and by providing a corresponding soundtrack, the video gave me a much finer, and more precise understanding of the make-up of a typical large city. I

[7] *Pour l'instant, j'aurais du mal à répondre à cette question.*

liked the gradual layering.

xiii. Listening to the transposition in sounds of the monuments, offices, markets, trees of Boulevard Sebastopol opened me to the possibility that this way of interpreting the urban dimension may in fact help to develop a deeper understanding of the city in which I live. The legend of the sounds can help either from a point of view orientation, ie to understand exactly where we are located, either from an overall point of view. In fact, the composition of the Boulevard Sebastopol as a whole is surprising for the particular personality and inspires me to think about what would be the result of other applications of the SUM to other roads or cities.[8]

xiv. I think SUM uncovers two types of rhythms in a city: the inherent rhythm of ambient sound in noisy places like markets and schools, and then the slower rhythm of changes as you travel through different areas. With respect to the latter, in a way I'm not even aware of it while I'm walking in the city itself. I'll go through crowded places and more silent areas but will not perceive the inherent rhythm consciously. By accelerating these rhythms and caricaturing them somehow, SUM makes these more explicit.

xv. I never really "listenned" to the sound of the city, so it makes me aware of how much one can learn by doing that.

xvi. It does. It makes me thinking beyond; moving objects like cars and people with which you have to share the space in the city.

xvii. I didn't know there is an office at the lower part of Bld Sebastopol! SUM can increase the awareness through carefully selecting sounds to make sure they are INTUITIVE. The markets sounds used in SUM are one good example of how this can increase awareness of neighbourhoods. Some of the sounds selected are less intuitive and may not yield the same result (increase of awareness)

xviii. It is hard to say that it increased my awareness of the rhythms in the city as I have walked in the city and know what happens. But I believe that it can definitely reveal things about an unknown place or a given moment in the city.

xix. Through presenting multiple perspectives, and sonically presenting local rhythms with respect to both a given trajectory and a large-scale urban framework.

xx. Rhythms of urban design and morphology were kind of surprise for me. The overall feel of the city may now be decomposed as well!

---

[8] *Ascoltando la trasposizione in suoni dei monumenti, uffici, mercati, alberi di Boulevard Sébastopol mi sono aperta alla possibilità che questa maniera di interpretare la dimensione urbana possa in effetti aiutare a sviluppare una conoscenza più approfondita della città in cui vivo. La leggenda dei suoni può aiutare sia da un punto di vista orientativo, ossia a capire esattamente dove ci si trova, sia da un punto di vista complessivo. Infatti, la composizione di Boulevard Sébastopol nel suo insieme sorprende per la particolare personalità e mi spinge a pensare a quale potrebbe essere il risultato di altre applicazioni del SUM ad altre strade o città.*

xxi. Obviously, sound augmentation [field recordings+synthesis] is very affective to depict the different rhythms; I think the rhythm has both a real and a abstract part. However, the use of a cursor scanning the streets did not totally satisfy me.

xxii. New and repeated sounds drew my attention to the variety and placing of different aspects of the city, and made me realise that these might be more intentional and "beautifully" placed than I had first realised!

xxiii. Probably quite a lot, I never thought at a city as something with different rhytms

xxiv. maybe the amount of bins...

xxv. multiplicity of perception, condensation of repeating structures in a more easily percievable timescale

5. **How could SUM further enhance your experience?**

i. It would be interesting to see how the rhythms of the city change along the day. If a region that's really busy in the morning remains so in the afternoon, for instance.

ii. If it was combined with mobile technology, it could serve as a giant audio guide. If I was looking to locate a business, like a restaurant, nightclub, hardware, and bookshop – this approach could help me understand how to design the interior and exterior. I could use interactive feedback form other users to determine which routes they prefer to take when navigating the city and alter the sound profile of my business making it more attractive. If I was looking for a home- house flat apartment, this could be useful to understand the activities that occur outside on the street – I could choose the hustle - bustle or the calm.

iii. I imagine this an interesting tool (maybe together with visuals) to represent aspects such as days of the week, daytimes, but also weather

iv. I would like to play with it myself to test out different routes, i.e. interactive SUM. I would like to compare the aural patterns of my city with those of other cities.

v. It could give the listener/user a sense of the overall plan of a city and provide an experience of moving through a city without actually being there. For a sight impaired person it could also enhance the experience of actually moving through the city.

vi. By offering a reminder of the elements of the city that often go unseen or forgotten. Bringing forward the more agreeable aspects (parks, monuments, community, historical importance even) of city living.

vii. I'm curious for contrasts between different kind of neighborhoods, i.e., how does an "ugly", or "dangerous" neighborhood sound like. Could I be able to learn with SUM whether I would like an area? Further data from crime rates or traffic accidents could be integrated - although on the other hand, that might make the overall experience less beautiful. It could also be interesting for users to be able to pre-define interests and use this information to set emphasize different aspects.

viii. I think we could move forward by making a local exploration of SUM.[9]

ix. I would say that SUM would make me more aware of my surroundings and help me to make daily decisions based on my sound experience. For example, whether I choose to take the metro or bike, or whether I choose a boulevard for rapidity or a detour in a park. I would be interested in learning the effect of the construction of the city on the psychology of its inhabitants based on the sounds it produces.

---

[9] *Je pense qu'on pourrait avancer en procédant à une exploration locale de SUM.*

x. It is very enjoyable to navigate. It feels like an engaging sonic game which at the same time allows you to explore the city and discover a lot of things, a lot easier and in a greater detail than you could possibly do by physically walking around.

xi. Being an auditory description of the city it is a new point of "view" on it, so that I can see it differently.

xii. I was sometimes confused by the musical choices attached to certain physical realities, ie flowing water for water was fine but for education I didn't understand the choice and there were a few like this. This confusion prevented me from fully participating in the experience. The moving dot maps were very effective summaries, more use of these would be welcome.

xiii. The application of additional SUM could reveal a particular aspect of the city of reference. It could actually prove that urban planning can affect the rhythm of the city outlining a particular personality and orientation of the dynamic over time of the masses. In essence, it would increase the awareness of my own rhythm of life.[10]

xiv. Back to my pragmatic mind: I think SUM would help me a lot if it was using real sounds captured from different parts of the city, or if it was using a clear (and clearly explained) encoding scheme between local city features and synthetic sounds. That would be a totally different way of rediscovering a city I know, or of discovering a city I don't know. The auditory aspect is completely lost when we use most (if not all) mapping and tourism tools online. I'm talking about the mobile sonification demonstrated at the end of the video. I did not find the global sonification of Paris that useful, mostly because the sonifications seemed arbitrary to me: so they don't tell me much. The mobile variant was interesting because at least I get the transitions, and I understand things are different from a location to another. Maybe the global sonification could be helpful in comparing different cities, and probably even more so if the sonification was based, as I said before, on actual samples captured within the cities or on clear auditory encoding schemes.

xv. I have no idea!

xvi. Controlling the point where you are freely, i.e. controlling an avatar. I'd like to sonify people's activity (cars, busses, bars, cycles)

xvii. I would love to select some of the sounds which I am interested in (e.g. if I am not interested in trains and metros, I would like to be able to unselect them and do the exercise only with the stuff I want to know (e.g. bins, trees, markets, offices, roads, shops, etc) . As mentioned above, it would be great to be able to zoom in and out of streets, and SUM could then provide all the sounds which are present in the level of

[10] *L'applicazione di ulteriori SUM potrebbe rivelare un aspetto peculiare della città di referenza. Potrebbe effettivamente dimostrare che la pianificazione urbana può incidere sul ritmo della città delineandone una particolare personalità e un orientamento della dinamica nel tempo delle masse. In sostanza accrescerei la consapevolezza del mio stesso ritmo di vita.*

zoom selected.

xviii. I would be interested in observing how the rhythms change over time, e.g., from morning to night, from Monday to Sunday, or from summer to winter. I would be also interested in comparing the rhythms of different cities. I can imagine the use of SUM in the metro and the trains, where the passengers hear the rhythms of city on the ground as they move from one station to the other. I would really like to see that working!

xix. This project could spiral out in many directions--e.g., comparisons of rhythm at different times of day, conveying differences in overall sound level at various locations, the ability to traverse the city at different "tempi," etc.

xx. -

xxi. Mixing together the contribution of different elements of the same area, discarding the time scanning would increase my global awareness of the city.

xxii. It represented an experience of the city in a different way, and listening to the music helped me to not take things for granted that I normally would.

xxiii. I will be more careful to the sounds I hear when I'm in the street

xxiv. ...

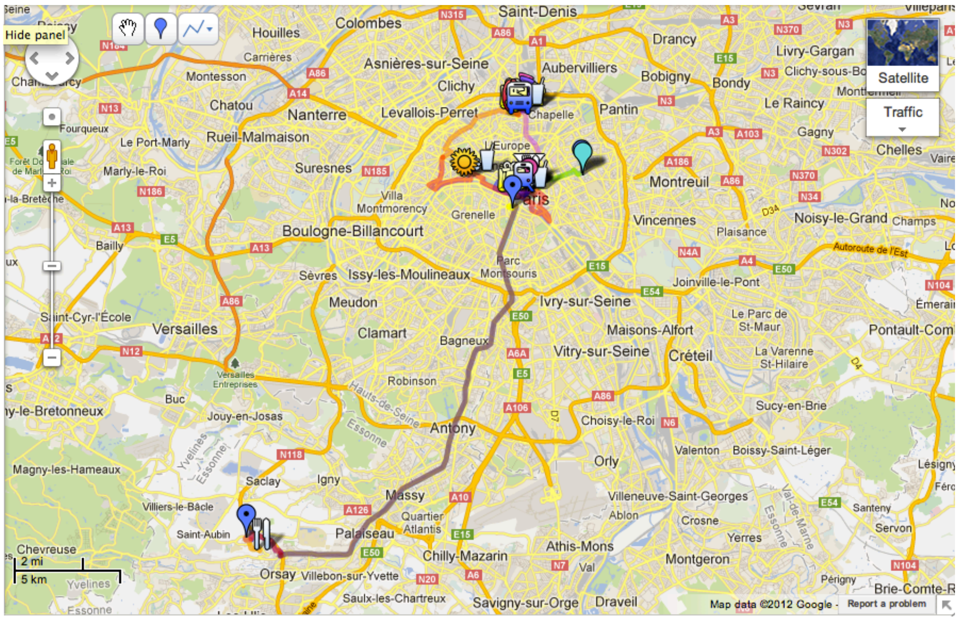
xxv. by being totally interactively scannable

II. Questionnaire 2: Urban Space-Time-use Survey

Mapping exercise : Daily space-time-use

An experiment was conducted in which subjects living and/or working in Paris were asked to map their typical weekday rhythm, according to the following instructions:

1. Using My places on Google maps, draw the path of your typical weekday (from and to home).
2. Place a pointer or icon to indicate all your destinations (home, work, shop, bar, theatre etc.). Draw a line to indicate your chosen route/s. (streets for walking, metro line, RER, etc.)
3. In the attached dialogue box that appears with each pointer/ line, specify the time (9:00, 21:00), mode of transport (bus, foot, metro, RER etc.), a description of the place and reason for the journey (work, study, dinner, sport, music etc.)



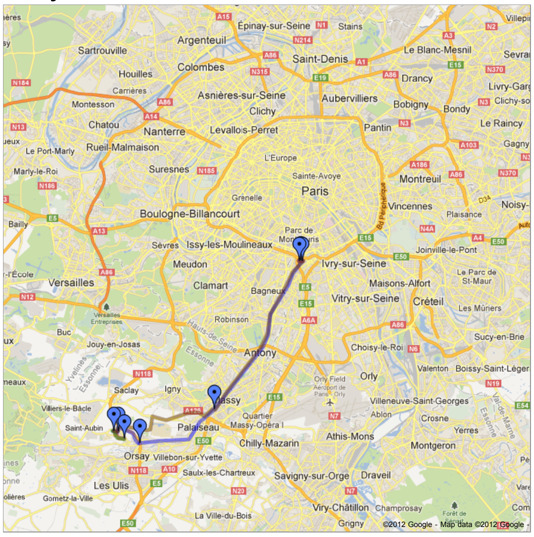
Participants:

Subject	Occupation	Live	Work/Study	Transport
1	Doctoral student	Luxembourg	Orsay	RER
2	Researcher	Gentilly	Orsay	RER
3	Engineer	Aubervilliers	Le Plessis-Robinson	RER
4	Freelance teacher	Aubervilliers	Varies	Metro-walk
5	Job seeker	18eme	Varies	Metro-bus-walk
6	Composer	Cite Intern.	Chatelet	RER-metro
7	Administration	Belleville	Chatelet	bike
8	Composer	Cite des Arts	Chatelet	walk

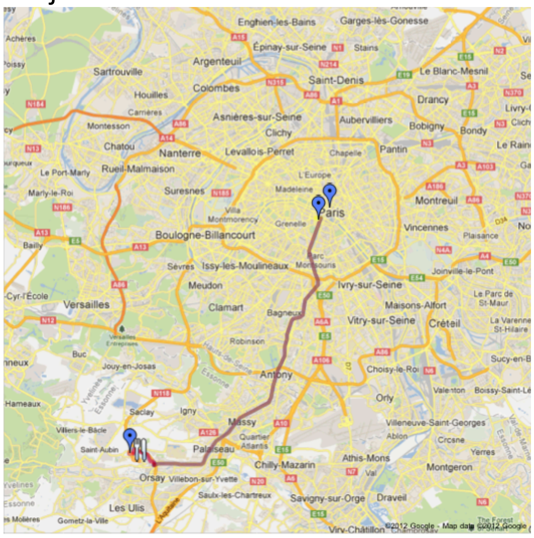
Daily Urban Space-Time Rhythms

Regional :

Subject 1

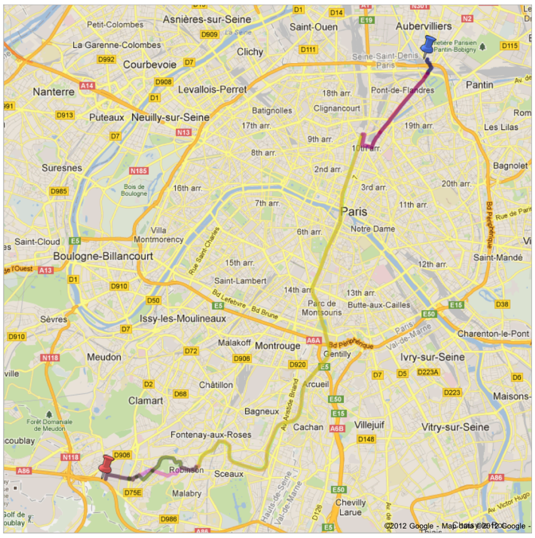


Subject 2

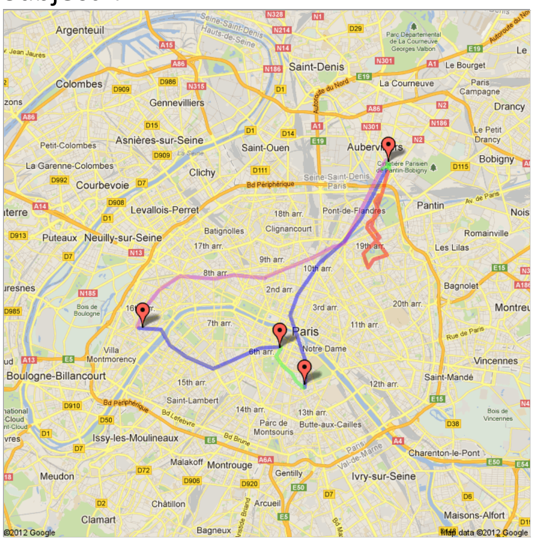


Peripheral :

Subject 3

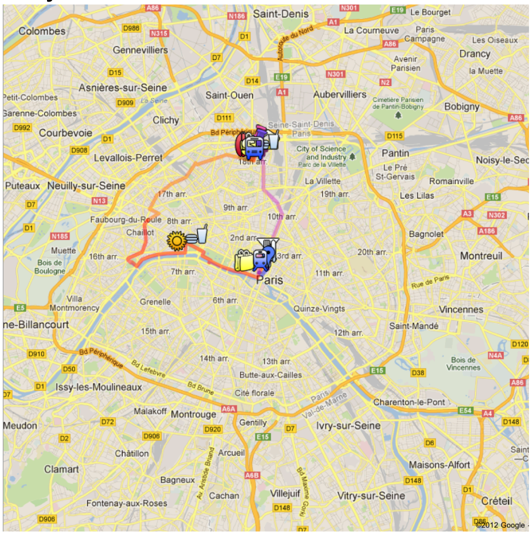


Subject 4

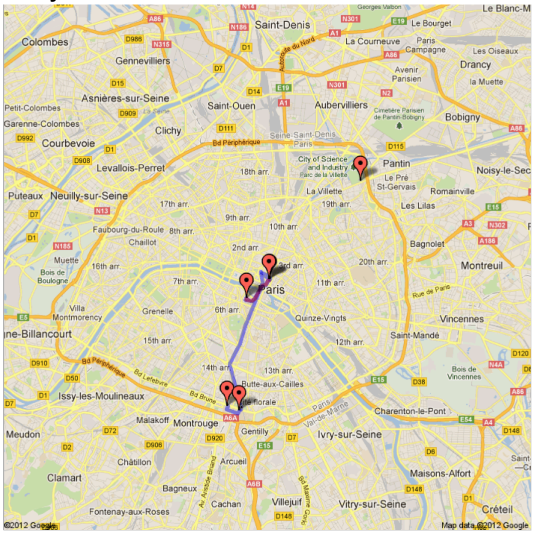


Metropolitan :

Subject 5

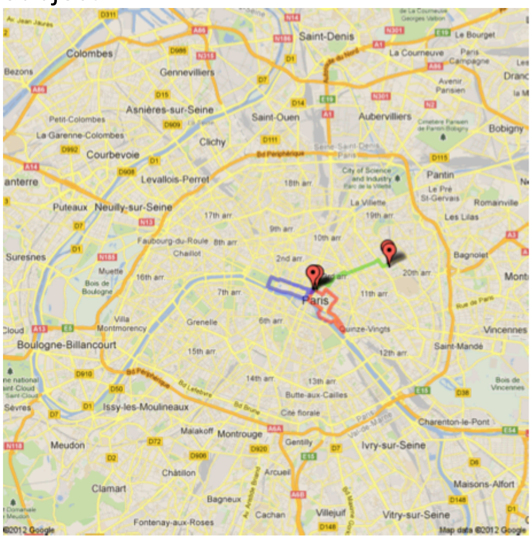


Subject 6

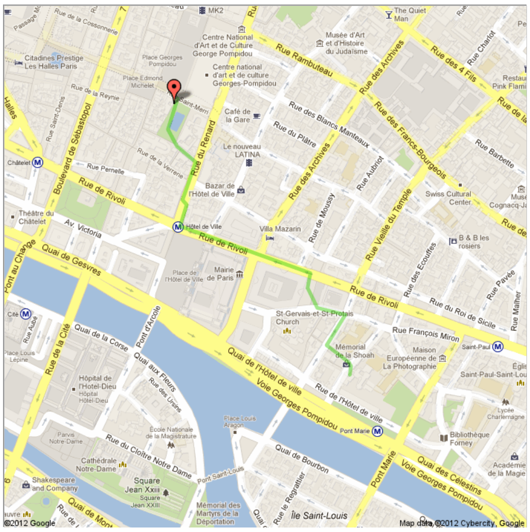


Inner-city:

Subject 7



Subject 8



Questionnaire 2: Daily Urban Space-Time-use

Participants were then asked the following questions relating to their typical weekday journeys from home to work:

HOME-WORK LOCATION – *choice of neighbourhood*

1. Where do you live and why ?
2. Where do you work/study and why?
3. Is your home location related to your work location (or vise versa) ? How?
4. Would you change your home/work location or connection and how ?

TRANSPORT INFRASTRUCTURE – *choice of transport mode*

5. How do you get from home to work /study and why ?
6. What determines your choice of path ?
7. How much time do you spend commuting and is it acceptable to you?
8. How satisfied are you with your transport service ? Specify problems or suggest improvements.

CHOICE OF PATH – *preferred street design*

9. What is your preferred street along your current path and why ?
10. What do you like about this path ? What do you dislike ?
11. Favourite street/quartier in Paris and why ?
12. Least favourite street/quartier and why?

Summary of Results: Space-Time-use Questionnaire 1

Travel time:

Level of statisfaction	*Time spent commuting*
1. Not at all	3h (TGV)
2.	1.5h (RER)
3. OK	45 min (metro)
4.	30 min
5. Very satisfied	8 min (walk)

- *Long, infrequent, breakdowns, crowded*
- *Fastest route, walkable, well-serviced*

Neighbourhoods:

Preferred Quartiers	*Unpopular Areas*
Canal St Martin	La Defense
Le Marais	Les Halles
Odeon/ St.Michel	
Montmartre	
Oberkampf	

- *Lively, animated, green, bars/cafes,'historical' architecture*
- *Commercial centre, sterile, underground,'modern' architecture*

Streets:

Preferred Streets	*Unpopular Streets*
Rue Duhesme	Bvd Jourdain
Rue Mont-Cenis	Bvd Rochechaourt
Butte aux Cailles	Bvd Ornano
Bvd Richard Lenoir	
Pont des Arts	

- *Walkable, interesting, lively, animated, pedestrian-orientated*
- *Car traffic, fast, large-scale*

Participant Groups :

The 8 participants were then divided into 3 groups of 3[11], each of varying rhythms.

Group A

Subject	Rhythm	Live	Work/Study	Transport
1	regional	Gentilly	Orsay	RER
6	metropolitan	Cite Intern.	Chatelet	RER-metro
5	metropolitan-multi	18eme	Varies	Metro-bus-walk

Group B

Subject	Rhythm	Live	Work/Study	Transport
2	regional	Luxembourg	Orsay	RER
8	inner-city	Cite des Arts	Chatelet	walk
4	periphery	Aubervilliers	Varies	Metro-walk

Group C

Subject	Rhythm	Live	Work/Study	Transport
3	periphery	Aubervilliers	Robinson	RER
7	metropolitan	Belleville	Chatelet	bike
9	metropolitan	13eme	Chatelet	bus

[11] Subject 9 was not included in the study

Listening Experiment 1: Sonified Daily Urban Rhythmanalysis

Dear Participant,

You have previously taken part in a mapping exercise in which you mapped your typical daily rhythm and answered a Space-Time-use Questionnaire. Please refresh your memory by taking a minute to look at your Space-Time-use map:

https://maps.google.com/maps/ms?msid=218305903057699851866.0004cfdeae0a311b9676c&msa=0&ll=48.756641,2.254601&spn=0.123581,0.249939

This is the second part of the study, in which you will listen to your daily urban rhythm 'sonified'. It takes approximately 30 minutes and requires your attentive listening, so please find a quiet place where you can perform this study in one sitting. Use headphones if you have them and don't forget to set the volume on your computer!

For your convenience, the following instructions are attached in PDF format.

INTRODUCTION: Your Sonified Daily Urban (SDU) Rhythm

This experiment involves you listening to your daily urban rhythm, which has been sonified according to your space-time map. Only your principal transport means and activities have been sonified (ie.walking is included only if it is your primary transport means), according to the following 'Urban Sonic Code'.

PREPARATION:

A: Urban Sonic Code

Here the Urban Sonic Code will be explained to you in a short video.
There are 3 groups of sounds : TRANSPORT, ACTIVITY, AMBIENT.
Each sound lasts 3-5 seconds and will be played to you TWICE.
Please watch the following Video 1 ONCE:

Video 1: https://www.dropbox.com/s/3y1w0z65kaznexi/SUM_survey_UrbanSonicCode.mp4

B: Listening Exercise 1

Now you will do a short Listening Exercise. You will be played a sound from each group – TRANSPORT, ACTIVITY or AMBIENT. Your task is to identify the sound. First, please open the following Questionnaire 1, ready to submit your answers:
Questionnaire 1: http://www.surveymonkey.com/s/D65GBSR

Now, listen to the following Video 2 TWICE:
Video 2: https://www.dropbox.com/s/02ztbk6fetpf8f8/SUM_survey_ListeningExercise1.mp4

Now you are ready to begin the Sonified Daily Rhythm Listening Experiment.

LISTENING EXPERIMENT 1: SONIFIED DAILY URBAN (SDU) RHYTHM

This listening experiment is organised into 2 PARTS.

PART 1: Your Sonified Daily Urban (SDU) Rhythm

Your daily rhythm has been sonified according to the above Urban Sonic Code.
Your day has been proportionally reduced in time to ~ 1 minute.
One hour is represented as a 4 second block. (15 min/sec)
Your SDU rhythm will be played to you TWICE.
Please listen carefully to the following Video 3 and then respond to the following Questionnaire 2: http://www.surveymonkey.com/s/VLZVRNB
Video 3: https://www.dropbox.com/s/vndtafxtvhyuv1n/SUMpathsC_S3.mp4

PART 2: Identifying your Sonified Daily Urban (SDU) Rhythm

You will now hear 3 different SDU rhythms, one of which is yours.
Please listen carefully to the video ONCE. Each SDU rhythm will be played TWICE.
Your task is to identify YOUR SDU rhythm amongst the 3 rhythms you will hear.
Don't forget to note down the number of your SDU rhythm (1, 2, or 3).
To start, click the link below:

Video 4: https://www.dropbox.com/s/0zywo4xwwtbofml/SUM_survey1_sonifications.mp4

Once you have identified your SDU rhythm, please fill out Questionnaire 3: http://www.surveymonkey.com/s/7DL3WZZ

You have now completed the Listening Experiment.

II. SUM as an Analytical tool

Questionnaire 2A: Your Sonified Daily Urban Rhythm

2. Describe your initial impression of your daily SUM rhythm. (aesthetic, emotional, rational response)

3. How did SUM help you think about your time distribution in the city? (time spent commuting, working, socializing...)

4. How did SUM help you think about how you navigate the city? (eg. transport mode, service, and route)

5. How did SUM increase your awareness of the impact of the city on your daily rhythm? (opportunities and constraints due to urban structure)

6. Is there anything else you learnt from listening to your daily rhythm?

7. Does hearing your rhythm make you want to change anything about it? (eg. how you spend your time, the composition of your day)

Responses 2A: Your Sonified Daily Urban Rhythm

2. **Describe your initial impression of your SDU rhythm. (aesthetic, emotional, rational response)**

Rhythm regional

Subject 1: I found it quite monotonous but very reasonable and consistent with respect to my expectations. Notice that I hadn't given enough details about going out (bar/cinema, which represent paces that are not fixed), there result does not fully represent my daily activities.

Subject 2: Pretty nifty, it was very cool to listen to my day as if it were a piece of music. It was also very easy to identify what each sound type meant in the context of my typical day.

Peripheral

Subject 3: It shows that I spend a lot of time in the office environment.

Subject 4: It was easy to distinguish and recognize the sounds. I like the sound running makes. The sounds are pleasant, but I feel that they are a little too cliché. For example, eating sounds like a restaurant, but you are not often in a restaurant eating - you can be at home or outside.

Metropolitan

Subject 5: Listening to my SDU has stimulated my attention and my curiosity. My mood was tense in trying to recognize all the elements. Finally, some sounds, such as walking, really evoked through the rhythm, the sensation felt at that particular point on the route.[12]

Subject 6: it's hard to imagine the duration, maybe some small breaks would help, the sound is represented well [13]

Inner-city

Subject 7: Continuous, monotone, linear, boring

Subject 8: funny

[12] *Ascoltare il mio SDU ha stimolato la mia attenzione e la mia curiosita`. Il mio stato d'animo era teso nel cercare di riconoscere tutti gli elementi. Infine, alcuni suoni, come il camminare, hanno veramente rievocato attraverso il ritmo, la sensazione provata in quel determinato punto del percorso.*

[13] *c'est difficile d'imaginer la durée, peut-être ca aiderai des petites pauses, le son resprente bien*

3. **How did your SDU rhythm help you think about your time distribution in the city? (time spent commuting, working, socializing...)**

Regional

Subject 1: It made obvious that I spent too much time commuting to work.

Subject 2: It made it very clear that most of my time is spent either in the RER or at work.

Peripheral

Subject 3 : The length of the sounds showed that I spend a lot of time in public transporation and in the office. Since the sounds represent the principle means of transportation only, it shows that walking and leisure and negligible parts of my day.

Subject 4: I spend a lot of time commuting.

Metropolitan

Subject 5: I think my SDU reflects not only the rate of one day in particular, but also the things that are important to me and to which I would not like to give up, such as dedicating some time to walking, to my friends, and to take advantage of the many opportunities of the city.[14]

Subject 6: I've realized that I spend a lot of time in transport [15]

Inner-city

Subject 7: too much work

Subject 8: I have understood better the time proportions in my life, and how many hours I work every day.

[14] *Penso che il mio SDU rifletta non solo il ritmo di una giornata in particolare, ma anche le cose che per me sono importanti e alle quali non vorrei rinunciare, come dedicare un po' di tempo a camminare, ai miei amici, e approfittare delle tante opportunità` della città`.*
[15] *j'ai m'ai rendu compte que je passe beaucoup de temps dans le transport*

4. **How did your SDU rhythm help you think about how you navigate the city? (eg. transport mode, service, and route)**

Regional

Subject 1: Much of my navigation takes place our of the city so there was no much variety. I think that I am quite aware of my own schedule so the SDU did not really change the way I think about my activities.

Subject 2: My SDU rhythm made it very sonically clear how dependent I am on the RER and how much time I usually spend in it.

Peripheral

Subject 3: The rhythm shows that I spend a lot of time in transportation (RER and metro) and at work.

Subject 4: My navigation of the city is pretty diverse, but too much time spent in the metro.

Metropolitan

Subject 5: My SDU demonstrates the fact that I like to vary depending on the situation: metro, bus, walk, rer ... I'm not a fan of one means of transport in particular. I like to vary.[16]

Subject 6: it gives me an overview of the path that I have [17]

Innercity

Subject 7: not enough of poetry in comparison with what I live, feel

Subject 8: I saw the differences between the time that I'm working, and the time that I'm travelling every day.

---

[16] *Il mio SDU riporta il fatto che mi piace variare a seconda della situazione: metro, bus, camminata, rer...non sono fun di un mezzo di trasporto in particolare. Mi piace variare.*
[17] *ca me donne une vision globale du parcours que je ne tenais*

5. **How did your SDU rhythm increase your awareness of the impact of the city on your daily rhythm? (opportunities and constraints due to urban structure)**

Regional

Subject 1: No much. I think that several details of were not captured well. For example, part of my walking from my office to the restaurant takes place near a forest, but this was not captured in the sound. I guess that this is due to the lack of this information in Google maps.

Subject 2: It made the constraints very evident, especially how much my typical day is shaped by the whole process of going to work in the beginning of the day and coming back to Paris at night.

Peripheral

Subject 3: In a way we have to do things as the city wants us to do it. We are forced to use the transportation that is available even though it might not be the most enjoyable.

Subject 4: I am forced to spend a lot of time in the metro because of the distribution of the city and the long distances.

Metropolitan

Subject 5: My SDU helps me to understand how the city really affects my rhythm of life. To take a metro, a bus, have appointments far or close together immerses my day in the rhythm of the city. This rhythm has to deal in some way with my inner rhythm with the challenge of a dynamic adaptation over time. Sometimes this comparison gives positive outcomes, at others disastrous.[18]

Subject 6: yes, it helped me to better understand how the city affects my everyday rhythm [19]

Inner-city

Subject 7: not a surprise

Subject 8: The city has little effect on me, because I'm working many hours. I can work more, because I spend little time travelling.

[18] *Il mio SDU mi aiuta a comprendere come la citta` incida veramente sul mio ritmo di vita. Prendere una metro, un bus, avere appuntamenti distanti o vicini tra di loro immergono la mia giornata nel ritmo della città`. Questo ritmo deve confrontarsi in qualche maniera con il mio ritmo interiore con la sfida di un adattamento dinamico nel tempo. A volte questo confronto da esiti positivi a volte disastrosi.*

[19] *oui, ca m'a aide a comprendre mieux comme la ville affecte mon rythme de chaque jour*

6. **Is there anything else you learnt from listening to your daily urban rhythm?**

Regional

Subject 1: I cannot think of anything else. I would be more interested in listening to the daily urban rhythm of someone else.

Subject 2: It was interesting to see how proportionally little time I spend on the actual streets, walking, in comparison to all the time in the RER and at work.

Peripheral

Subject 3: It makes me want to change how I spend my time and reduce transportation, but the city does not leave me any other options.

Subject 4: It makes my lifestyle seem pretty active.

Metropolitan

Subject 5: Listening to my SDU, I remembered, now that work, how much I like to walk and spend some time to simply wander. The SDU is also a good means of self-analysis.[20]

Subject 6: Perhaps the noise of the city [21]

Inner-city

Subject 7: sounds are different during WE

Subject 8: I am working too much.

[20] *Ascoltando il mio SDU, ho ricordato, ora che lavoro, quanto mi piaccia camminare e dedicare un po' di tempo al semplice gironzolare. L'SDU e` anche un buon mezzo di autoanalisi.*
[21] *Peut-etre le bruit de la ville*

7. **Does hearing your daily urban rhythm make you want to change anything about it? (eg. how you spend your time, the composition of your day)**

Regional

Subject 1: Yes, I would like to commute less to go to work!

Subject 2: It does make me even more aware of the constraints imposed by my RER-dependence, and also makes me wish I could spend more time walking, which is something that I usually really enjoy doing.

Peripheral

Subject 3: Spend less time in public transportation in order to have more leisure time.

Subject 4: Of course, I would like to spend less time in public transportation.

Metropolitan

Subject 5: I missed the element of office \ work and the element of education \ study, two things that I'd like to include back into my day.[22]

Subject 6: maybe yes, paths with less noise [23]

Inner-city

Subject 7: I can't change so I do not dream

Subject 8: I would like to do more things in my quotidian life.

[22] *Mi mancava l'elemento ufficio\lavoro e l'elemento educazione\studio due cose che vorrei riuscire ad includere di nuovo nella mia giornata.*
[23] *peut-être oui, de parcours avec moins de bruit*

Questionnaire 2B: Identifying Your Sonified Daily Urban Rhythm

2. Which daily SUM rhythm did you identify as yours?
3. How did you identify your SUM rhythm? (eg. by memory, exclusion, recall of your actual rhythm?)
4. How easy or difficult was it to identify your SUM rhythm? (Easy, Relatively Easy, Average, Quite Difficult, Difficult)
5. Explain any difficulties you may have had in identifying your daily SUM rhythm and how identification may be improved.
6. Did listening to the other SUM rhythms change your impression of yours? How? (comparison of length, speed, variety etc.)
7. As a result of this listening exercise, would you want to change anything about your daily rhythm? (shorter/longer, faster/slower, more/less variety)
8. Finally, describe any other thoughts you may have regarding your daily urban rhythm, resulting from this listening experiment.

Responses 2B: Identifying Your Sonified Daily Urban Rhythm

2. **Which SDU rhythm did you identify as yours?**

All 8 subjects identified their SDU rhythms correctly

3. **How did you identify your SDU rhythm? (eg. by memory, exclusion, recall of your actual rhythm?)**

Regional

Subject 1: By memory but also by trying to reproduce in my mind the sound according to my day schedule.

Subject 2: Memory

Peripheral

Subject 3: By memory

Subject 4: A combination of these reasons. I could easily pick out the sound of running, and I don't work in an office.

Metropolitan

Subject 5: It was the only one with the sound of the office.[24]

Subject 6: By hearing and memory [25]

Inner-city

Subject 7: Memory, exclusion, recall

Subject 8: By memory, and identifying sounds that I am never using. By exclusion.

4. **How easy or difficult was it to identify your SDU rhythm?**

All selected 'Easy', out of a 5-level scale of ranging from Easy to Difficult

5. **Explain any difficulties you may have had in identifying your SDU rhythm and how identification may be improved.**

No difficulties nor improvements suggested.

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[24] *Era l'unico senza il suono dell'ufficio*
[25] *Pour la ecoute et la memoire*

6. **Did listening to the other SDU rhythms change your impression of yours and how? (eg. comparison of length, frequency, variety etc.)**

Regional

Subject 1: There was much more variety, less commuting and visits to public places and markets in the second and third one. I would much prefer them!

Subject 2: It made it very clear how much variety my rhythm lacks in comparison to the other two.

Peripheral

Subject 3: Yes, the comparison of the length and the dynamic of the sounds were interesting. It was also interesting to hear the variety.

Subject 4: I'm happy to not work in an office, but I perhaps spend more time in public transportation. It is difficult, however, to compare the different SDU rhythms since each person's day is so unique.

Metropolitan

Subject 5: Yes, my SDU is much more varied.[26]

Subject 6: Maybe, because the first works a lot more and the last did many more activities[27]

Inner-city

Subject 7: the third one was funny I was trying to understand at what time this personn was eating, just the comparison of way of life

Subject 8: I saw that I don't take so much public transport like other people, and this is nice!

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[26] *Si`, il mio SDU e` molto più vario.*

[27] *Peut-etre, parce que le premier travaille beaucoup plus et le dernier faisait beaucoup plus d'activites*

7. **As a result of this listening exercise, would you want to change anything about your daily rhythm? (shorter/longer, more/less frequent, more/less variety)**

Regional

Subject 1: Yes, more variety, less RER commuting,more entertainment.

Subject 2: There isn't much that I can change in my actual daily routine, since it's totally shaped by work and the RER. If I could, though, I would definitely add more variety.

Peripheral

Subject 3: I would say more variety.

Subject 4: Less transportation.

Metropolitan

Subject 5: Yes , I would like to introduce the sound of the office/work and of education/study. [28]

Subject 6: No

Inner-city

Subject 7: less working...

Subject 8: Less work, more variety

[28] *Si`, vorrei introdurre il suono dell'ufficio/lavoro e dell'educazione/studio.*

8. **Finally, describe any other thoughts you may have regarding your daily urban rhythm, resulting from this listening experiment.**

Regional

Subject 1: This was a very typical rhythm of my a week day. I would like to listen and compare the signification of different days of my week or see its evolution from day to day, month to month or year to year...

Subject 2: -

Peripheral

Subject 3: It's interesting to hear the sonic description of my quotidian.

Subject 4: It's interesting to see how your day can be simplified into sounds. It makes you see your day in segments instead of one continual flow.

Metropolitan

Subject 5: It has been very pleasant to listen to my SDU and I am very curious about how could be others that I have not yet heard. This study could also have an implication of a sociological nature.[29]

Subject 6: it is interesting to compare different urban rhythms, it gives an exterior view of the actual rhythm[30]

Inner-city

Subject 7: work sounds : it could be improved by proposing two kind of work as speaking /exchange with people or not, no rest is suggested in the sounds

Subject 8: -

[29] *E`stato molto piacevole ascoltare il mio SDU e sono molto curiosa di come potrebbero essere gli altri che non ho ancora ascoltato. Questo studio potrebbe avere anche un risvolto di tipo sociologico.*

[30] *c'est intéressant de pouvoir comparer de différents rythmes urbains, ca donne une vision exterior du propre rythme*

Questionnaire 3: SUM as a design tool

1. What were your initial thoughts regarding the SUM tool and the integration of sound in the urban design and planning process?

2. How could you see SUM being useful in the representation and communication of an architectural or urban project?

3. How could you see SUM being useful in the design and composition of urban experience?

4. Given the static nature of the traditional graphic masterplan, what do you see are the benefits of the temporality provided by SUM?

5. Given the visual limitations of layering in the graphic masterplan, how could you use the polyphony provided by SUM?

6. How could the appreciation of sonic rhythm in SUM impact your approach to architectural and urban design?

7. How could you envision the SUM tool being useful in your next design project or would you suggest any other features?

Responses 3: Urban Professionals

Subjects: Architects, urban designers, planners and engineers

i. Architect, Paris, France
ii. Planning & Engineering Officer, Perth, Australia
iii. Architect, Treviso, Italy
iv. Urban Designer, Perth, Australia
v. Architect, Forli, Italy
vi. Architect, Paris, France

1. **What were your initial thoughts regarding the SUM tool and the integration of sound in the urban design and planning process?**

i. Apprehending the auditory dimension of space as an integral component of the space-time continuum is an idea rich in potential as much from the point of view of design as it is from the point of view of research. As with any interdisciplinary tool, the key word is perhaps not only the tool itself, but its "interdisciplinarity" - its capacity to be the effective interface of several disciplines.

ii. Firstly I love it (just as my first - non intellectualised reaction). I found myself asking "are these really scientifically generated rhythms? or are they just nice little soundtracks created with samples related to the activity? It's practical, but incidentally, quite poetic.

iii. I find it very useful, and it makes me think of Time Geography. I think some more emphasis might be put on the criteria used to choose the sounds appearing in the video. I really like them, but they are somewhere between musical and realistic.

iv. SUM brings the aspects of time to the fore. Our traditional representations are a frozen slice of time, so it is something too easy to forget in the design process.

v. An opportunity to read the system "city" in a different way, getting more informations than the "classic" rappresentations (static map)

vi. The sound helps us enter a third dimension in a plan. We easily imagine the city. It is done very spontaneously. We can 'live' the plan and we are also connected in a temporal dimension. This new dimension considers data not really previously recognized. The software also gives us a human scale, it helps us to easily consider the impact of the city on its residents.[31]

[31] *Le son nous aide a rentrer dans une troisième dimension dans un plan. Facilement on imagine la ville. il se fait très spontanément. On peut 'vivre' le plan et nous connecté aussi dans une dimension temps. Cette dimension considère des nouveaux donnés pas vraiment pris en compte auparavant. Le logiciel aussi nous donne une échelle humaine, ils nous aide a envisager facilement l'impact de la ville sur les habitants.*

2. **How could you see SUM being useful in the representation and communication of an architectural or urban project?**

i. The sonified representation of an architectural project, from an architect's point of view, is at first consideration of indirect interest. The SUM tool could offer a novel appreciation of the work which may be a liberating factor for designers. As an appreciative tool, it is fundamentally external or a posteriori to the design process. The appreciation is given after the work is conceived or even completed. It is perhaps possible to extend the use of SUM beyond that of an "appreciative tool" to that of an "analytical tool". However, to make this leap, it seems that one fundamental question has to be answered - What is the relationship between the "signifier" and the "signified". How are they chosen ? By which protocol or convention is it decided that "bells" represent "churches" and so on?

ii. I found the added dimension of sound helps me "see" the map better. It's like I now realise that all this time, the maps and plans which I work with as a planner have had something missing, but I'm only just realising it. This might be only in the early stages of development, but I can see a future for sound to be incorporated into planning / urban design It also draws attention to the need for planners / urban designers to move away from static maps, because life and especially transport are not static, yet the maps and plans we use are.

iii. It can be helpful by introducing the dimension of time, representing a user's experience of time through the project. As for graphics, I think it could be implemented both with 'mimetic' (realistic) sounds, and with 'abstract' ones in order to underline different 'hidden' aspects of the project. In the first case it could turn into a sort of 'sound rendering', in the second into a sort of 'sound diagram'.

iv. SUM brings to mind experiences and memories of the impact of time/rhythm in our understanding of the city and how it works. So yes very useful in allowing a more prominent appreciation of city rhythm.

v. First of all, the sound can help blind people, so it could be a good instrument to draw a map into the head of people who cannot see. Then, the sound/video way has one information more than a static paper map: time line. It would be interesting to understand how much influence has got the sound on the perception of the city, not only for researchers, but also for the citizens.

vi. The representation of the urban experience by the inhabitant... amazing! The sound is an experience inscribed in time, so the communication of an urban project may become an experience inscribed in the time which enables a better understanding. Above all by people that are not accustomed to the reading or the interpretation of two-dimensional plans.[32]

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[32] *La représentation de l'expérience urbaine par l'habitant…incroyable ! Le son c'est une expérience inscrit dans le temps, donc la communication de un projet urbain peut devenir une expérience inscrit dans le temps qui permettra une meilleur compréhension. Surtout par des personnes que sont pas habitué a la lecture ou l'interprétations des plans en deux dimensions.*

3. **How could you see SUM being useful in the design and composition of urban experience?**

i. It is not difficult to imagine that SUM could be useful in the urban design process either as an "appreciation of existing spaces" or as a "generator of new and meaningful form".

ii. I think the use of rhythm to show how a city functions is useful in helping us "see" what we're working with.

iii. It gives the possibility to shape the experience and to verify the layering of elements and the patterns during time. I find it very useful for the rhythmic coupling of audio-visual material, but the audio itself can provide more informations indeed.

iv. There are many aspects I could imagine designers utilizing for design. The SUM tool can be applied to lots of urban settings and design options.

v. I think SUM would be useful to define a new alphabet, another language to design the city. If i think of Architecture as an expression of citizen culture, I say yes, SUM could help urban design. But i think we are in front of a question: should we use music composition rules to draw the city, or should we use architectural rules to play music? To define a new composing language we should first define the letters of our alphabets, as Mr Kevin Lynch did on his research on "The image of the city".

vi. Having to consider a series of data in this case, the sound of each space, open or closed, helps the consideration of the experience of the pedestrian or cyclist or driver as an element to be taken into account when defining a project. It allows you to enter a scale that, despite the distance, can make a small scale such as 1: 500 or 1: 1000, very difficult to imagine the reality of the street or the daily experience.[33]

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[33] *Le fait de devoir considérer une serie de donnes dans ce cas le son de chaque espaces ouvert ou fermé aide a considérer l'expérience du piéton ou cycliste ou conducteur comme un élément a prendre en compte au moment de définir un projet. Permet de rentrer dans une échelle que malgré la distance que peut faire une petite échelle tel que 1 :500 ou 1 :1000, très difficile de imaginer la réalité de la rue ou l'expérience du quotidian.*

4. **Given the static nature of the traditional graphic masterplan, what do you see are the benefits of the temporality provided by SUM?**

i. The SUM tool renders tangible the fact that objects composed in geographical space are inherently objects composed in temporal space. As such, temporality can be collected, represented, analysed and recomposed. We can say that temporality is "demystified".

ii. As mentioned above, I think it draws attention to the need for planners / urban designers to move away from static maps, because life and especially transport are not static, yet the maps and plans we use are.

iii. It's exactly because it transforms it from static to dynamic, and providing informations (especially about experience, but not only) which are usually 'hidden', thus not considered by planners and designers.

iv. Allows everyone in the design process access to an understanding of time/temporality/rhythm. It puts it on the table and not forgotten.

v. The city is not a static system, it's made up by spaces that change in time, minutes, hours, days, nights, seasons, years... and sometimes they are repetitive. Reading at these aspects by using sounds, it could be helpful to understand the rythm of the city, the relations between spaces.

vi. This helps to take into account the experience of trajectories. To add the given time allows us to know already what will be the experience of a project, closer to reality than a photo or synthetic image, because each person relates the sound with his own images. His own experience of the city.[34]

[34] *Ca aide a prendre en compte l'expérience des trajectoires. ajouter le donné temps permet savoir quelle sera déjà le vécu d'un project, plus proche de la réalité que une photo o une image de synthèse parce que chaque personne met en rapport le son avec ses propres images. Son propre vécu de la ville.*

5. **Given the visual limitations of layering in the graphic masterplan, how could you use the polyphony provided by SUM?**

i. The polyphonic dimension of SUM is perhaps both a liberation factor and a limitation. It is liberating in sense that we can not see all graphic layers at the same time, but it is possible to listen to a polyphonic composition. It is limiting is the sense that one can not listen "ad-infinitum" where as one can look at graphic layers as if they are suspended in time. Both are actions are necessary depending on our investigation.

ii. I would have to have a go at using SUM, but as a transport planner/ traffic engineer, I think it would help me "see" the interaction between commuters better. Transport planning and traffic engineering practice (where I work anyway) is carried out in a very abstract way, and is therefore generally carried out by people who think in abstract ways (engineers). As a non engineer, I think the incorporation of sound (and motion) would make the work I do feel more real, and I would find it easier to engage with my work. Currently I find traffic engineering for the assessment of large subdivisions and structure plans (which is my job) can be quite dry and boring. I think using this kind of tool would change that.

iii. To me it seems a very powerful representational tool, most of all. And representation is fundamental for analysis. The 'musicality' can be a limit, but this can (must?) be developed as a representational and artistic choice by the planner, i think. According to the chosen sounds, i.e. (harmonic, dissonant, field recordings, sine waves, ...) the representation of the same data can change radically. It makes me think of the way 'polyphony' and 'rhythm' are described by Deleuze and Guattari in 'A Thousand Plateaus", referring for example to Messiaen's music but also to environments in the wider sense.

iv. the polyphony maybe useful in allowing movements of things to be a part of the masterplan layering

v. I think this is a limitation of a top point view: while sounds gives more informations through the space to the listeners, a static map is just a 2D information, i think there should be 3D graphic information.

vi. Precisely it allows countless variations and a possibility to convey things in more detail.[35]

[35] *Justement permet une infinité de variations et une possibilité de suggérer des choses de plus en plus spécifiques*

6. **How could the appreciation of sonic rhythm in SUM impact your approach to architectural and urban design?**

i. An awarement of sonic rhythm acts as a reminder for designers to engage the temporal dimension design, that this engagement is more immediate than we think. The SUM tool provides concrete means to do so. For example, it would be impossible to conceive of a pedestrian promenade without bring in consideration the pace at which we walk.

ii. I think it would help me engage in my work with more interst, as the added sensory dimensions would make what I was looking at more real, and less abstract. I would be able to employ my instinct and common sense when considering land use and transport integration, not just policy, not just the "rules" I learned at uni. I would not have to try so hard to imagine what the plan would look like on the ground, as I would be given more to work with.

iii. Finally, it will open architects' ears and mind towards sound and time as very important components of planning!

iv. I think the movement of things in space is not part of the drawings and so it is difficult to conceptualize collectively. I think it is the collective capacity of SUM that is very useful

v. I think it could be another instrument to help the design, to determine rules to apply to the project. I hope to use this instrument in my future projects.

vi. The architecture becomes less abstract, and at the same time connects us more easily with the temporal experience of the project. The experience that one can have once the architectural project is built.[36]

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[36] *L'architecture devient moins abstract, et en meme temps nous connecte plus facilement avec l'experience temporel du projet. L'expérience que on peut avoir une fois le projet d'architecture est construit.*

7. **How could you envision the SUM tool being useful in your next design project or would you suggest any other features?**

i. An clear area of appllication of the SUM tool could be on projects where "movement" is a central theme, such as the design of urban promenades, bus stations, railway stations or highways. It is also possible to imagine the SUM tool being used to compose façades and/or landscape layouts.

ii. Like I said, I would have to play with it to really understand how it works, but I think it would be useful simply in drawing more attention to the important dimensions of movement, interaction of land use and people moving through land use, and I think if we all started using this added dimension, then we (as practitioners) would all start thinking about planning in a more holistic (cities as living organisms) kind of way.

iii. I think the possibilities of new features could be many. I really like the possibility of representing the presence of functions (education, monuments, etc.). It might be interesting to provide a more accurate 'formal' representation (i.e. considering the 3D, and thus height, but also the wall/glass relationship of elevations, the colors, and many other measurable and non measurable qualities). It would be also interesting to represent flows and concentrations of people, of transportations, of mobile data, of money, etc.

iv. Design option analysis, and the capture of memories understandings and readings of the existing city and the proposed city would be particularly interesting as an exercise.

v. I think it would be interesting to start thinking not just on playing the city by the top view, as a map, but also by the front views, as prospects in the streets, or by particular perspective views (maybe the more interesting for the citizens) and hopefully, in 3D space, such a 3D sound

vi. For example it is very interesting to know the sounds around the environment. It could eventually show the customer how the project takes into consideration the environment ... a school on one side, a park on the other. In general we make only summarised images or at the limit a small video with music. With SUM, we can really show how the architectural project responds in a concrete way to its environment.[37]

[37] *Par example c'est très intéressant savoir les sons autour du terrain. Pourrai éventuellement montrer au client comment le projet prend en considération l'entourage…un école d'un coté,, un parque de l'autre. En général on fait que des images des synthèses ou a la limite un petit vidéo avec la musique. Avec SUM on peut vraiment montrer comment le projet architectural réponde de façon concret a son environnement.*

Appendix 5:
Urban Design Project

VAUXHALL's
REJOUISSANCE

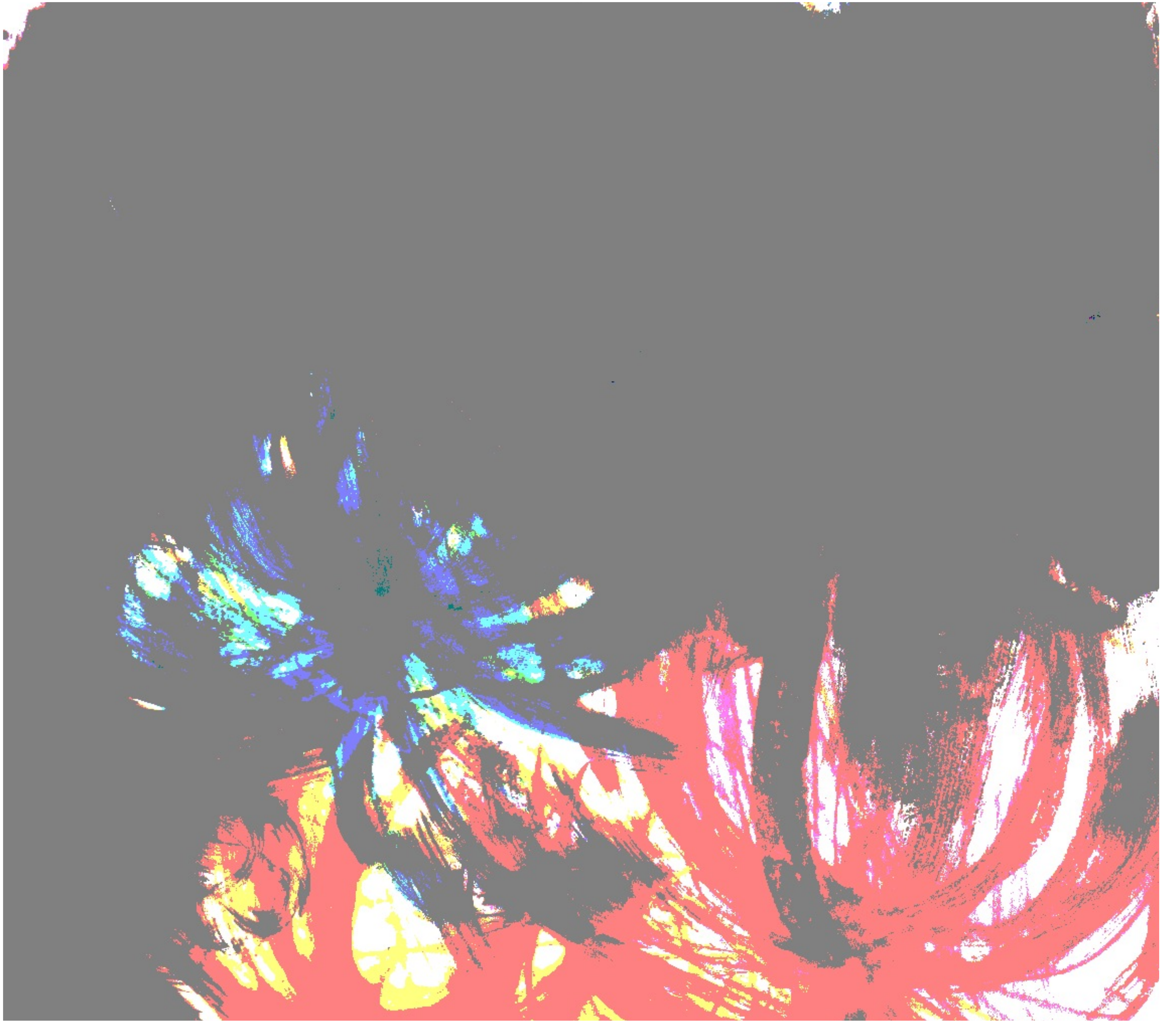
The rhythms of fire and water as expressed through Handel's music created for performances on the Thames waterfront to inform networks of community spaces.

A series of pontoons **front the river between Lambeth and Vauxhall bridges.**

A concourse **inspired by the music of fire sits behind the pontoons involving a play of water edges.**

Stems **then connect thematically from the pontoons through the concourse to the parks and gardens within the community.**

The parks and gardens **are thematically set on popular music themes.**



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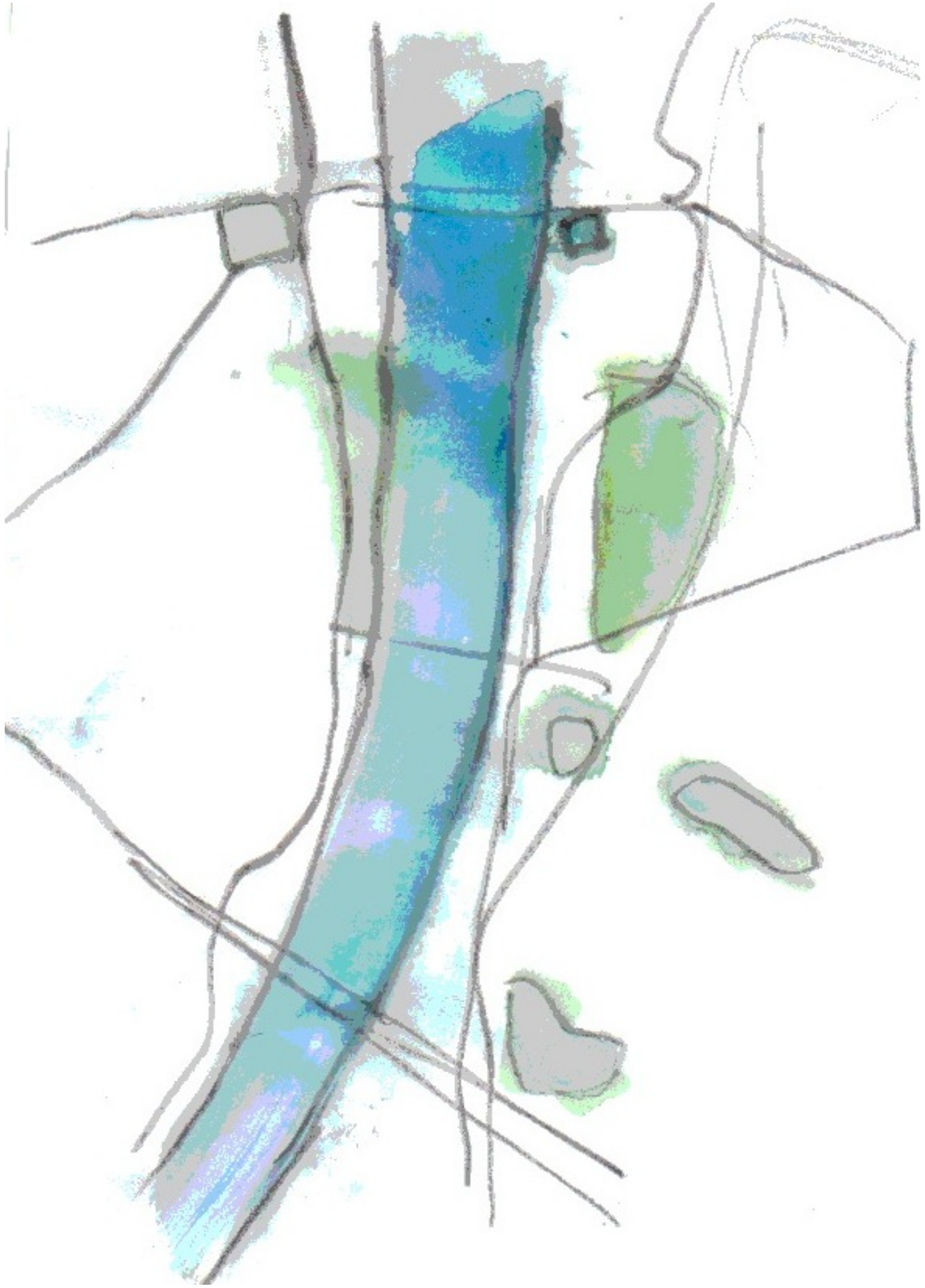


TIMING

The passage of time is considered as a piece of music. It is a time of reverie, to sample the subtleties of existence, as a movement, a walk, a dance. So often a design is seem from a distance, hovering above a place from an impossible standpoint, everything condensed in the one moment, not even a second. Music is appreciated through time, just as a walk is experienced through time.

The designs of paving, sculptures, lighting, seating, performance spaces all are spaced and positioned from two pieces of music, Handel's Water Music and Music for the Royal Fireworks, which situates music into their originally designed performance site on the Thames. The water and fire form a double path, that sits along side the river. This is grounding for the area, a spine that focuses a performance of human movement. It is imagined that people will change their step, inspired by the timed placement of objects in their path.

A piece of music is a metaphor of a path and we are composing urban experience through music. We chose when something happens not just where, the course through the environment is traced as significant, encouraging the very movement through its spaces by noticing and recording them. The movement of the very people the spaces are designed for record and utter every step taken to preserve the very nature of its inner workings, neither denying the very real and different experiences of the very same places we all have, depending on the very circumstances of our lives.

POLYPHONY

Polyphony describes the multiplicity of rhythms as ascribed to the city environs, from bins, to bus stops, trees to seats. Each positioning changes the experience. The interplay of rhythms can be perceived by passersby to be played with; so that the music of Handel becomes imbedded in the way people use space to become place. The interplay encourages play, allowing a finer side of life to become real, and the imagined concrete.

Each sound has an image which can be compared to a plant stem rising from its source of inspiration to grow according to its particular conditions. Just like each street has a stem and a flowering, connecting spaces, of play, work, communion, and restfulness. There are places of performace and places of renewal, of activity and rest. Just as a flower blooms in the day and retreats at night, and the full cycle of the year where growth retreats into the renewing soil only to give birth again in the spring. These cycles of life are often shown in music, its pauses just as important as the culmination. The river gives birth to its city, exciting and orientating our lives, drawing us all to its edges, as a talisman and a touchstone to our other presences.

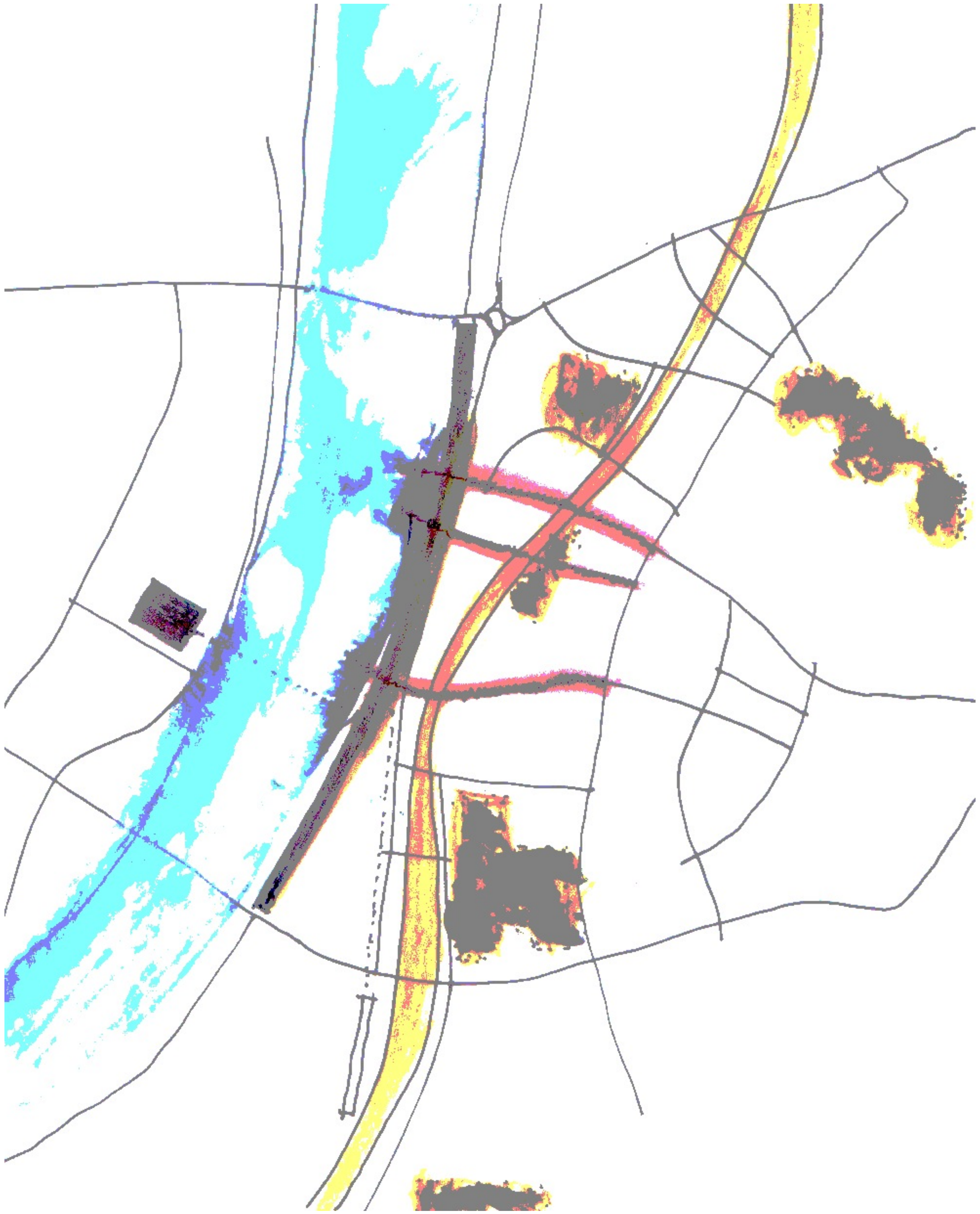
That journey to the river is celebrated through two pieces of music, entwining on the shore a bit like a vacant strand of dna waiting for a soul. Giving life and rhthym and being to the other places that flow from it. But there is always a rememberence of that place on the shore in all the other places we visit, knowing it is always there when we are not.

SYNCHRONICITY

The chance seeming coincidences of life becomes a layer of art that is lifted up into a mundane level of people's day-to-day life. The underplay of music defining and governing the rhythms of placements are not necessarily understood at first as music, and only slowly to the pieces come into being. It is a bit like a jigsaw puzzle, only seeing the little bits that connect with each other, and only much later seeing an overall integrated concept.

The layering of the city from a distance to the river, defines paths ways of growth, from which the energy and life of the river can breath into the undergrowth.

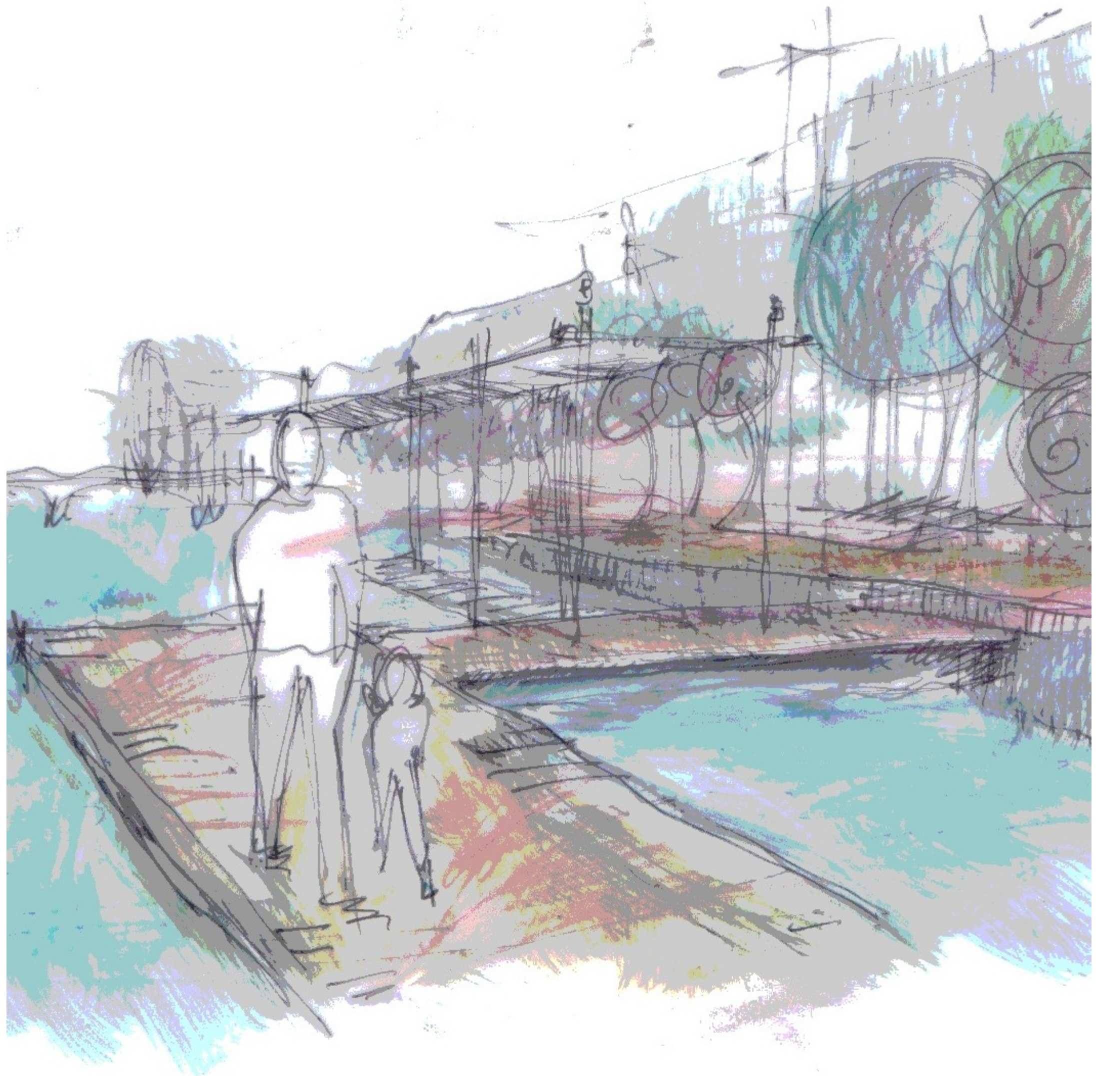
The three spines curling under the sinew of rail coil towards the river, received and played with a pontoon walk which layers the rhythms of Handel's water music in its patterning, paving and railing. Art works now have a focus for conversation, and play to engage, telling more stories of experiences to fonder recall. These spines further connect back to three park areas, which again are laid out according to a music patterning this time of Adele's "Set Fire to the Rain".

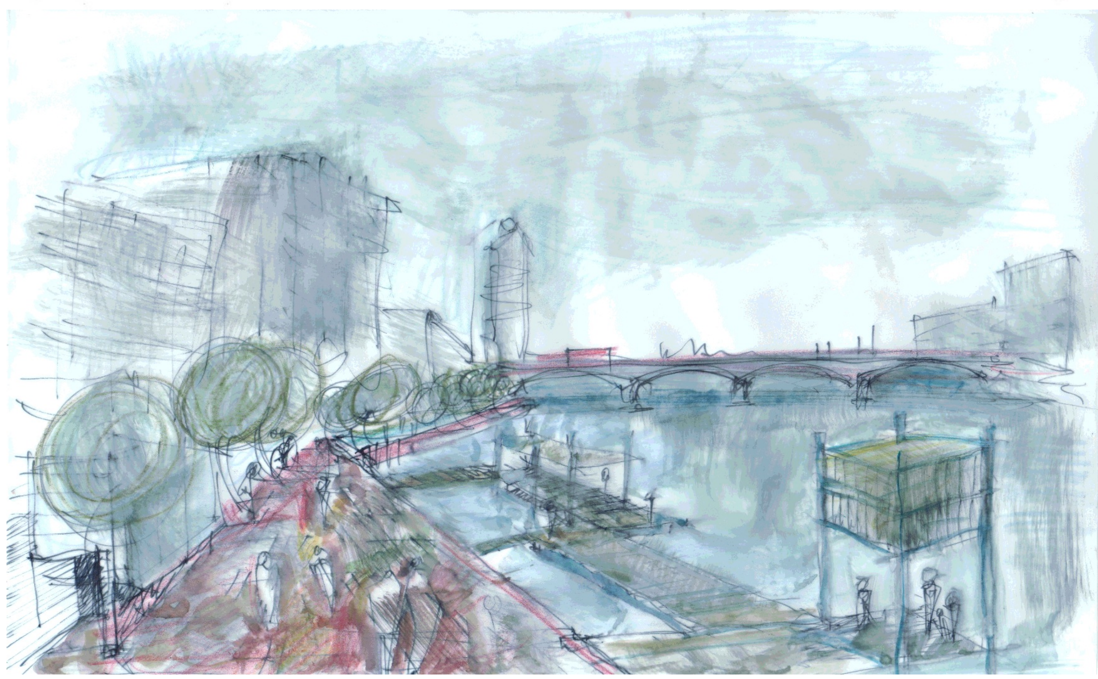


RHYTHM

Patterns of sound solidified in the ground, form the paving pattern and placement of shelter structures and performance spaces along the river. Finer levels of pattern differentiate tree plantings and reeds, water locations, and pontoons. The major statement is that the rhythm is as complex as a wonderful piece of music, not a regulated undifferentiated space, which has complete regularity from start to finish. The subtly feeling and mood, energy and function has organisation, not necessarily perceived as music. There is an interesting quality of accessing music from the solid the physical. Robust music becomes robust form.

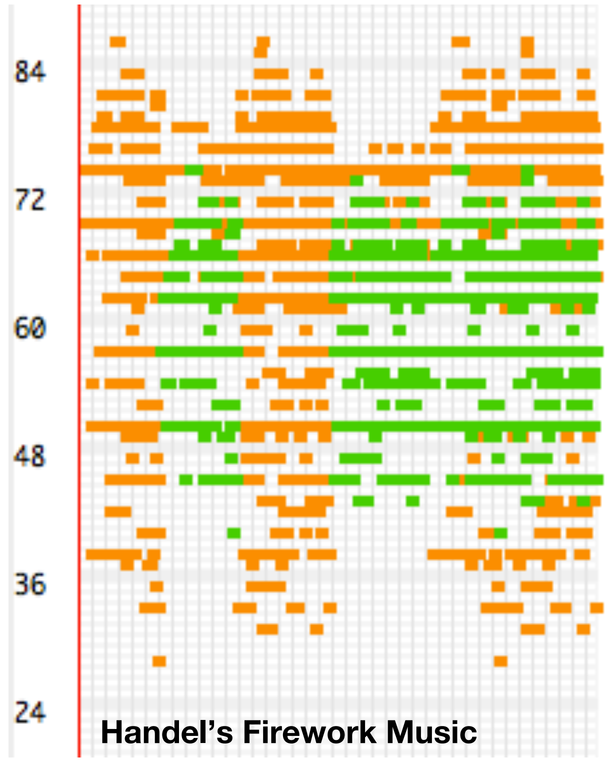
Edges intersecting become the confluence of rhythms flowing, merging, and integrating. The edge of the river does not become one experience but many, as many as the people who come to partake of the communion.

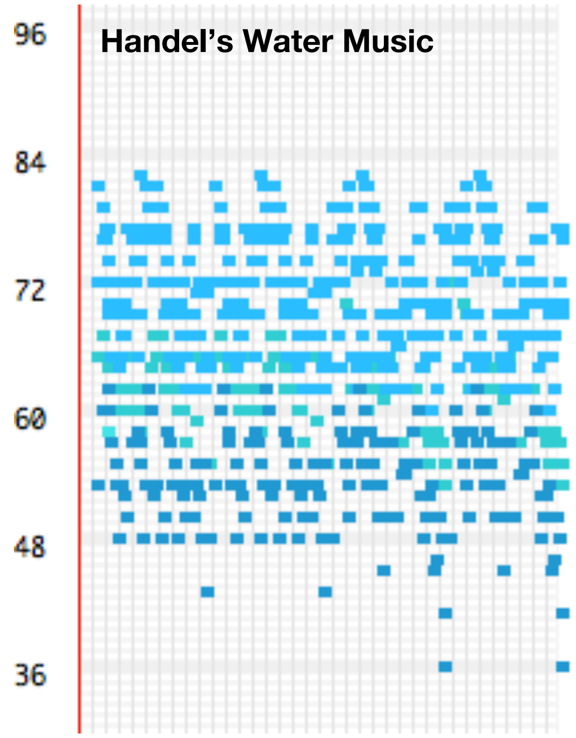




MUSIC

Melody is a narrative moving with the walker down the river. Then why not having side melodies splitting off down the streets, and through the bridges, finding there way into schools, and cafes. The melodies are stories of the players and the dwellers. Each street has its own songs, and the music encourages those songs to be created and enhanced, encouraging people to be more aware of the beauty of their own movements through the city and how each of these creates the hustle and bustle and excitement of everyday living.





SYMPHONY

Everything comes together in a symphony. The seventeenth of July 1717 was the date when Handel's music was played on the Thames for the amusement of King George I, later he composed music for King George II for a firework display. Handel's water music and the Music for the Royal Fireworks were both composed for outdoor performance. This musical history of the Thames forms a permanent showcase of rhythms and polyphonies. The everyday becomes the special. This does not mean the everyday becomes hidden forgotten or irrelevant, it just means that the everyday becomes celebrated, intensified, and made aware of. It is the everyday in a heightened state of awareness. IN the same way the design scheme can be appreciated on that subtle knowing everyday way, but we the have cues to celebrate that focus in on all kinds of bits of history, and locations of place in its highest sense.

FIRE and **WATER**

There is something about these primal elements don't you think? There is an uncompromising passion, forsaking nothing in its path. The heights and depths of life, emotion and inspiration. May be that is why Bachelard chose them for his dreams and reveries, they excite the potential of life, in its very destruction, life and death sit side by side as they always do, but for which we can hardly contain the day to day of living. The disguise their inner core…. Water not revealing its depths, we are left to wonder, the same with fire destroying its very fuel from which the flame takes shape. They are poems to conjure with in our everyday life, so it makes no sense and all sense to site the water music next to the fire music and they wait and watch and see what we do next…….


31
La Réjouissance
32
PRIMA VOLTA
SECONDA VOLTA
TERZA VOLTA
Allegro
Tromba I
Corno da caccia I
Tromba I Corno da caccia I
Tromba II
Corno da caccia II
Tromba II Corno da caccia II
Tromba III
Timpani
Violino I Oboe I
Violino II Oboe II
Viola
Violone
Fagotto I, II
Cembalo

Appendix 6: Publications

THE SONIFIED URBAN MASTERPLAN (SUM) TOOL : Sonification For Urban Planning And Design

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ABSTRACT

This paper describes the progress of an interdisciplinary project that explores the potential for sonification in urban planning and design. The project involves the translation of visual urban mapping techniques used in urban planning and design, into sound, through the development of the Sonified Urban Masterplan (SUM) tool. We will describe our sonification approach and outline the implementation of the SUM tool within the computer-aided composition environment PWGL. The tool will be applied to a selected urban data set to demonstrate its potential. The paper concludes with the advantages of such an approach in urban analysis, as well as introduces the possibility, within such CAC environments as PWGL and OpenMusic, to 'compose' urban plans and design using sound.

1. INTRODUCTION

Sonification, as a process of representing data through auditory means [1], has become increasingly utilised in scientific analysis since its introduction by Kramer in 1994. This is largely due to the efficiency of the ear in detecting temporal patterns, periodicity, and simultaneously following multiple parallel streams of auditory events [2]. In the social science of urbanism, concerned with numerous data flows, such a temporal representation technique can aid the understanding of their complex interrelationships.

The use of sonification in the urban realm has so far ranged from the analysis of various urban data sets [2], to the interactive sonification of geo-referenced data for navigation by the visually-impaired or for educational purposes [3]. Recently, the aesthetic potential of such urban data as a source for musical compositions has also become appreciated, as seen by the development of the COMPath tool [4].
However, the use of sonification as an alternative representative technique in the applied practice of urban planning and design, in the physical organization of such data, through built form, is still yet to be explored.

Thus this paper will explore the potential for sonification to not only aid representation for urban analysis, but to inform urban planning and design.

Currently, our work is realized inside PWGL [5], which is a widely-used Lisp-based visual CAC environment. This paper will present the computational model used in our approach. Moreover, it will discuss the development of a prototype of the Sonified Urban Masterplan (SUM) tool and present a language framework aimed at describing the sonification process.

2. BACKGROUND

Urban planning and design is an applied discipline, which must synthesise numerous datasets of information for design purposes. Occupied with space, its representation has traditionally relied on graphic means. However, while concerned with the organization and design of static objects in space, its effect on the urban system as a whole is inherently temporal.

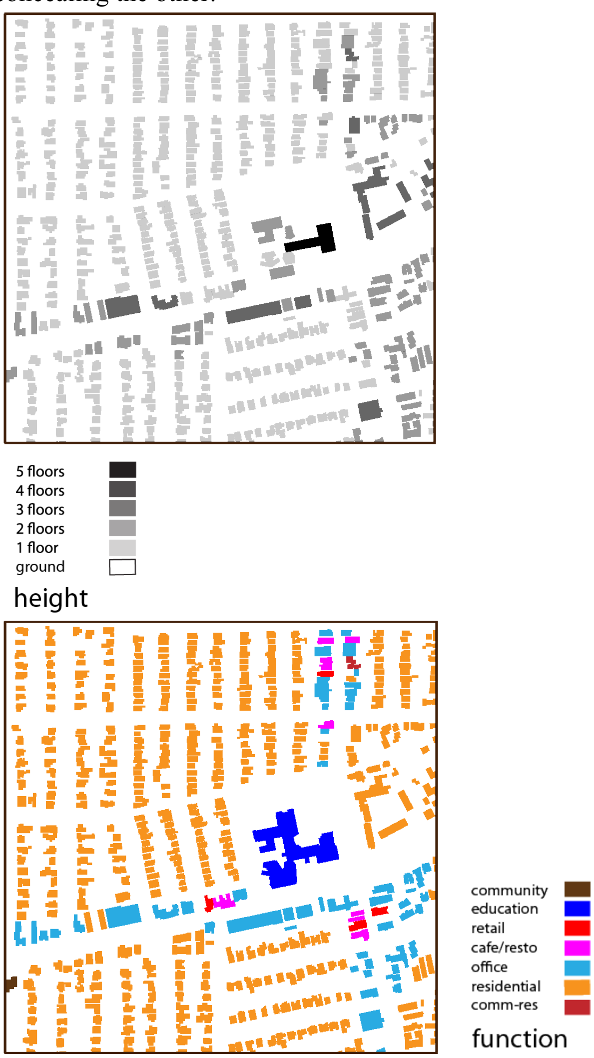
The static representation of dynamic urban systems can be seen to have contributed to the discrepancy between urban form, function and infrastructure in the post-industrial planned city. This can be seen in our following example of Perth, Australia, where the temporal needs of the pedestrian can be seen as largely neglected in relation to its car-scaled infrastructure.

The work of Sara Adhitya has been generously supported by the John Crampton Scholarship Trustees of Australia.
The work of Mika Kuuskankare has been generously supported by the Academy of Finland (SA137619).

Thus with urban planning being a temporal field, yet based traditionally on a static, visual representation technique, sonification can only help urban planners better identify and cater for their temporal demands.

3. ISSUES OF REPRESENTATION

The process of urban planning and design is reliant on its representation technique, usually involving the development of an overall graphic ‘urban masterplan’ from the synthesis of numerous other urban datasets. However, the representation of all these data attributes on the one map is constrained for obvious legibility reasons. Thus the data is often separated into individual maps. For example, Figure 1 shows two different data attributes of the same structural element: building height and building function; which would otherwise be difficult to represent on the one map without one map concealing the other.



Figures 1: 2 different attributes of the same structural element: building height and building function

However, for urban planners interested in analyzing the relationships between these multiple datasets, this separation due to visualization does not aid their synthesis.

Thus we propose the ability of sonification, through its own multiple attributes, to aid the simultaneous representation of multiple data attributes.

4. THE SUM TOOL

The Sonified Urban Masterplan (SUM) tool (see Figure 3) aims to synthesise the data of individual maps to be contained in one ‘sonified mapset’.

The user organises their data as separate maps according to their attributes of interest. These maps are raster images saved at 72 PPI, allowing each map to be read as a 1:1 matrix of pixels. RGB colour format is utilized and with each data attribute allocated a colour-value, the standard colour-coding conventions in urban planning can be adhered to. With transparency retained, an empty (transparent) pixel indicates the absence of data, while a filled pixel represents its presence. The layering of raster images produces a matrix of data, as illustrated in Figure 2.

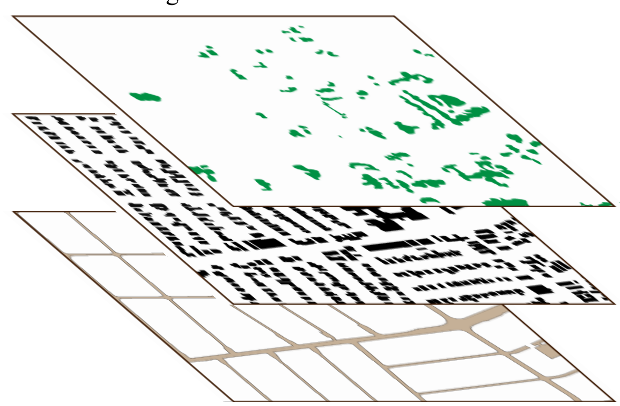


Figure 2: the layers of data form a matrix

The maps can be created in a graphic program such as Adobe Illustrator, commonly used in architectural and urban planning representation. Being vector-based, it allows the importation of .dxf files, a vector format in which cadastral data is usually available or exportable from standard GIS or CAD software. Within the program it allows its manipulation, and generation, to form the desired layers and their coding using colours.

Once generated, this mapset can then be loaded into the SUM tool (see Figure 3), where the sonification process

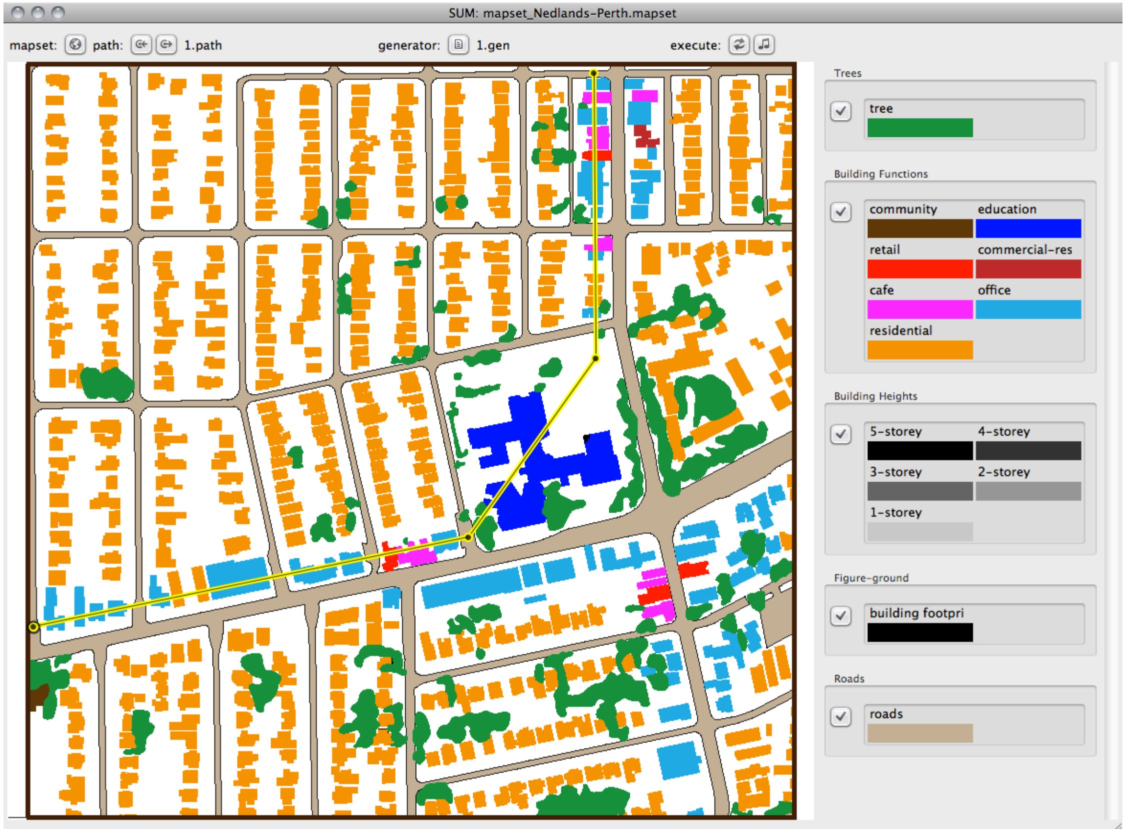


Figure 3: SUM tool user-interface displaying the current mapset (left), and the dataset legends (right).

can be defined. In our example, a 800m by 800m mapset of the suburb of Nedlands in Perth, Australia is displayed. This mapset is limited to include 3 urban structural elements (building, roads, and trees), of which one (building) has 2 sets of attributes (height and function).

5. DATA RETRIEVAL

In the SUM tool, the mapset becomes a type of open 'musical score', 'played' by the user drawing a polyline on the mapset over the areas of interest. This indicates which elements are to be played over time. To break the vector polyline into discrete sampling points the path is rasterized according to Bresenham's line algorithm. In our application, the order of the points is of importance as it determines the direction of the path along which the time progresses. Thus for a line extending upwards and to the left, the pixels would be sampled in the order shown in Figure 4. Each raster map image is then sampled pixel by pixel to retrieve the data of interest per each sample-point along the path. The playback speed is specified in terms of the duration of one pixel unit (termed 'unit-duration') in seconds.

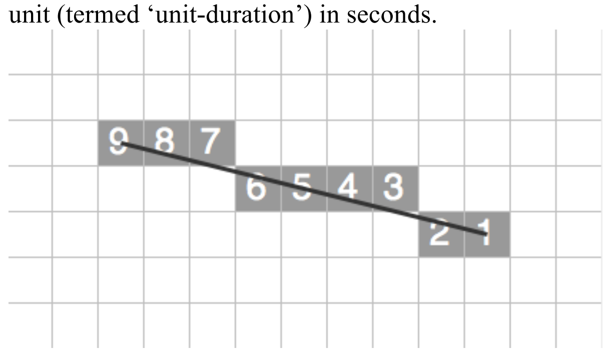


Figure 4: Diagram of Bresenham's line algorithm, with sampling order

6. SONIFICATION APPROACH

The sonification technique used is parameter mapping, in which various aspects of the data are directly converted in terms of the various attributes of the acoustic signal: pitch; volume; timbre; duration; and their overall temporal organization expressed as rhythm.

At this point, it is important to be able to experiment with different data-sources (mapsets), paths, and sonification processes. To this end, we have developed a language framework called SUMDL (sonified urban masterplan definition language), the native format of the SUM tool. Using the SUMDL, it is possible to describe the whole sonification process beginning from the dataset to the final musical score.

In the next sections we introduce the SUMDL language framework and give working examples regarding its usage.

6.1. The SUM Description Language

The SUMDL language framework consists of 3 domain specific languages: (a) a mapset definition language; (b) a path definition language; and (b) a sonification specification language. A set of packrat parsers [6] were developed allowing us to generate the various SUM tool objects out of SUMDL description files. The parsers are implemented using a Lisp-based packrat parser called 'esrap' [7] by Nikodemus Siivola. A packrat parser lends itself well for designing extensible and dynamic languages. The main idea behind the proposed languages is to allow users without extensive programming background to easily experiment with the system.

8.1 The Mapset Description Language (.mapset)

An example of a potential mapset description is given in Listing 1. Here, we define a mapset called "Nedlands, Perth" consisting of two maps. The 'legends' section is of primary interest in terms of the sonification process. It is used to enumerate the attributes of the given map. In this example, both maps have only one attribute. For example, the attribute provided by the first map is called "tree" and it is given an attribute called color with value ':green'. This information is used to convert the data represented by the map's raster image (given with the keyword ':image') into a list of numeric values. These values, in turn, are used in the sonification phase to transform the data into sound.

```
:mapset
 :title "Nedlands, Perth"
   :maps
     :map
       :order 2
       :title "Trees"
       :image "trees.png"
       :legends
         :legend
           :data-name "tree"
           :data-description :green
     :map
       :order 1
       :title "Figure-ground"
       :image "figureground.png"
       :legends
         :legend
           :data-name "building footprint"
           :data-description :black
```

Listing 1. A mapset defined with the help of the Mapset Description Language.

8.2 The Sonification Description Language (.gen)

The Sonification Description Language allows us to describe the mapping between the mapset and the resulting sound. The format (see Listing 2) consists of a score-generator description that can contain an arbitrary number of part-generators. Each part-generator defines the data-source, and the mapping between the resulting sound and the properties derived form the data- source. As an example, the following general mapping approach (Table 1) could be applied to each structural element. Each structural element could be expressed by a different instrument, allowing different functions to be acoustically identifiable by their differing timbres.

Table 1: Parameter-mapping of urban structure to sound

Structural Attribute	**Sound Attribute**
Height	Pitch
Function	Timbre
Density	Volume
Distance	Duration

In our example, we have mapped the building height (number of stories) to a chromatic scale above middle C, taken as the base note at ground level (see the part marked as pitch). Furthermore, the unit-duration is set at 0.06 to reflect the speed of the predominant transport infrastructure, the car at a speed of 60km/h.

```
:score-generator
  :part-generator
    :pitch
      :data-source "Building Heights"
      :post-process #'(lambda (h) (+ h 60))
    :volume
      :data-source ()
      :default 60
    :unit-duration
      :data-source ()
      :default 0.06
    :channel
      :data-source "Building Functions"
      :post-process #'(lambda (i) (case i
                              (0 "Tubular_Bells")
                              (1 "Celesta")
```

```
(2 "Glockenspiel")
(3 "Glockenspiel")
(4 "Vibraphone")
(5 "Marimba")
(6 "Xylophone")
(7 "Reverse_cymbal")))
```

Listing 2. The sonification process is described using the Sonification Description Language.

7. RESULTS

While working with this limited data sample, interesting results have been produced. These will be presented as audio files as part of the poster presentation, along with a demonstration of the SUM tool prototype.

Apart from the obvious temporal contrast between the experience of the urban morphology at the speed of the car, compared to that of the pedestrian, it is also possible to acoustically identify patterns of urban structure with their visual counterparts. It is possible to compare and contrast the difference between one zoned area and another, for example a residential street of repetitive 1-storey houses, compared to a commercial street of more varied function and form.

These preliminary results highlight the importance of the relationship between the scale of the built form and the speed of the transport infrastructure provided, in the creation of urban experience.

8. LIMITATIONS AND OPPORTUNITIES

Both a limitation and opportunity of this prototype tool is its flexibility. It is up to the informed user to first a) understand what he or she wants to analyse from the dataset, and then b) organise it into layers and sublayers, which will later allow c) the generation of the different permutations of interest. This means that, depending on the complexity of the data input, the possibilities are limitless.

The use of industry-standard software to produce these maps – AutoCAD, ArcInfo, and Adobe Illustrator – aims to promote its implementation by design professionals.

9. CONCLUSIONS

As the representation of those physical elements which construct the experience of an abstract body travelling along a selected path at a chosen speed, the SUM tool at this stage is essentially a sonified representation of urban morphology. While this method of sonification does not claim to express urban ‘experience’ in the perceptive sense, it attempts to represent those physical elements which construct it. However, these sonification results may begin to inform ‘urban soundscape compositions’ for musical purposes.

Of future interest is the sonification of whole areas, contained within polygons. This would allow the sonification of the overall urban ‘texture’ of a built environment.

The long-term intention of the SUM tool created within a CAC environment such as PWGL or OpenMusic, is to incorporate the use of sound in the urban planning and design process.

10. ACKNOWLEDGMENT

We would like to thank IRCAM, and in particular l'Équipe Représentations Musicales, for hosting us during this collaboration.

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[7] https://github.com/nikodemus/esrap

Audio-assisted Visualization – Sonification of Complex Urban Systems with the SUM tool

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ABSTRACT
This paper proposes the use of audio-assisted information visualization in the representation of complex systems, in particular that of the urban environment. It introduces the technique of sonification – the representation of data through sound – and demonstrates its ability to simultaneously represent multiple attributes. As a temporal medium, it can help to reveal complex urban relationships over time. Thus it can be viewed as well adapted to the urban design and planning profession, which must deal with the synthesis of numerous layers of visual data into one urban masterplan. Here we present the Sonified Urban Masterplan (SUM) tool, which utilizes audio to assist the visual representation of urban data.

Categories and Subject Descriptors
J5 [**Arts and Humanities**] Architecture; J6 [**Computer Aided Engineering**] Computer-aided design (CAD)

Keywords
Complex systems, Urban dynamics, Urban design and planning, Data sonification, audio-graphic information visualization

1. INTRODUCTION: AIMS AND BACKGROUND

Effective representation is critical in the design and analysis of a complex system, defined as 'a system composed of a typically large number of (possibly heterogeneous) elements that as a whole exhibit some properties which specifically result from the interactions between the constitutive elements.'[1] Here a system is seen as more than the sum of its individual parts, and thus the relationship between parts is crucial.

One of the most complex spatial systems is that of the contemporary city, consisting of numerous temporal urban flows interacting within a given spatial urban structure. However the complexity of spatio-temporal relationships produced by these various infrastructure systems, makes the resulting urban dynamic of difficult to predict.

This means that urban designers and planners, allocated the task of spatially organizing the urban system, are faced with the challenge of designing for increasingly complex spatio-temporal data. Traditionally based on visual representation techniques, a more time-based representation technique is called for.

The technique of sonification, defined as the process of representing data through auditory means [2], offers a more temporal form of data representation, utilising the efficiency of the ear in detecting temporal patterns, periodicity, and simultaneously following multiple parallel streams of auditory events [3]. Since its introduction by Kramer in 1994, the use of sonification in scientific analysis has grown dramatically. It can only aid the analysis of complex urban systems.

Furthermore, communication of urban design decisions to the general public is becoming even more challenging, along with the risk of miscommunication due to information overload. Within the climate of a democratic decision-making process, the effectiveness of acoustic communication can help bridge the gap between urban specialists and the general public, assisting in public education and promoting participation.

Thus this paper proposes the use of audio-assisted visualization in the representation of urban data, for the design, analysis and communication of our complex urban systems.

2. DESCRIPTION

The Sonified Urban Masterplan (SUM) tool, currently realized within PWGL [4], a widely-used Lisp-based visual CAC environment, allows the synthesis of multiple layers of graphic information into one sonified mapset.

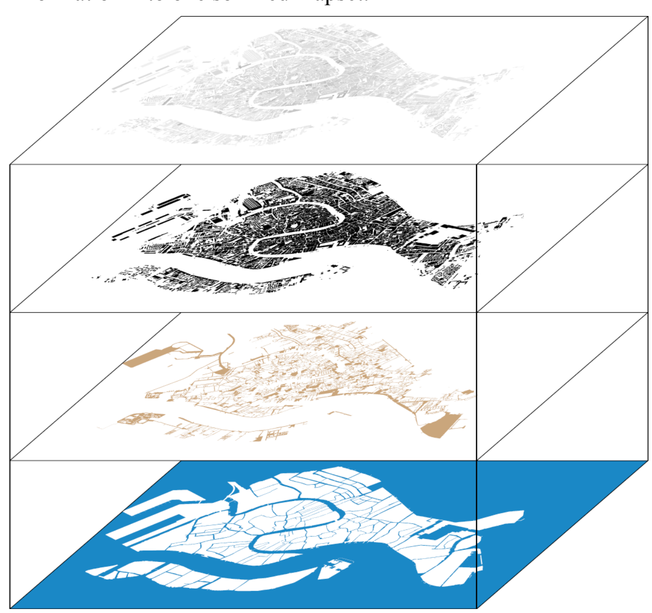

Figure 1. Superimposition of various layers of urban elements of Venezia to form a '3D matrix' of data

The tool supports the importation of any number of raster images. Saved at 72 PPI in RGB colour format, these images can be read as a 1:1 matrix of colour-coded pixels, according to a user-defined legend. Each filled pixel represents data, while transparency indicates its absence. When superimposed, these 2D data layers form a virtual '3D matrix' of pixels, called a 'mapset'.

It is up to the user to generate this mapset by organising their data into their layers of interest. In urban planning, for example, each layer can be used to represent a different urban element which, when superimposed, recreates the whole masterplan.

However, whereas the overlaying of graphic layers would normally mask the data of another, here the use of sonification allows the data to be heard, allowing relationships between layers to be effectively represented.

The sonification process consists of simple parameter-mapping implemented through our SUMDL lisp-based description language, where each colour is assigned certain acoustic attributes, such as pitch, volume or instrumentation, as desired.

In order to access this data, the user draws a time-line in the form of a vector polyline. Assigned a certain speed, the time duration of one pixel can be calculated and the image is sampled pixel by pixel accordingly. Multiple paths can be drawn, at differing speeds and with possible delays, allowing multiple flows of interest to be heard simultaneously or separately.

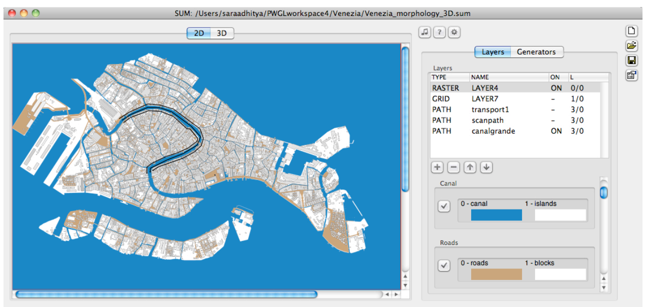

Figure 2. The SUM tool user interface - allowing multiple 2D graphic layers to be 'heard', even if unable to be seen

The SUM tool also supports the internal creation of 2D vector objects, allowing designers and planners to modify or create new graphic layers and immediately 'listen' to their effect on the existing urban system. Our current development towards the input and generation of 3D vector objects will aid the visualization of spatial environments.

3. APPLICATION AND RESULTS

There is great potential for the application of the SUM tool in the field of urban and regional planning, and its concern with spatially distributed systems and their temporal implications.

Able to represent multiple data layers simultaneously, sonification can make explicit the co-occurrence of different spatially relevant phenomena. As a temporal medium, it is just as effective in exposing complex patterns or correlations over time.

Thus through its integration of sonification and visualization, the SUM tool has the ability to reveal spatio-temporal relationships. This allows the communication of the temporal effects of a spatial structure, indicating possible outcomes such as urban sprawl.

Being a computer-aided design tool in itself, it provides designers and planners with a more time-based approach to spatial design.

Furthermore, the power of acoustic communication can help bring together expert and lay knowledge, promoting public education and participation. The SUM tool can thus be useful to social organizations as a mediating tool within the participatory decision-making process.

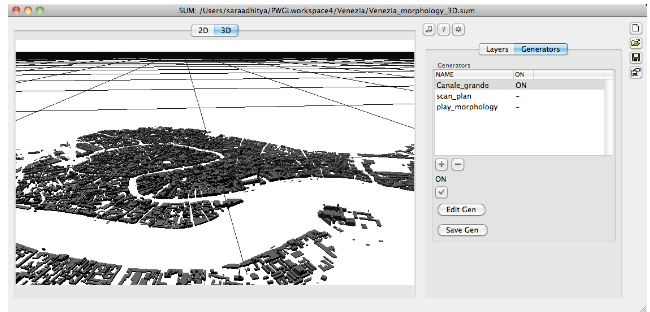

Figure 3. 3D visualization in the SUM tool

Beyond application within the field of urbanism, the SUM tool can also be used to represent other complex spatial systems. The flexibility of raster-input permits any visualization, including that produced by other software, to be imported. The relationship between any combination of visual data sets can be sonified.

4. CONCLUDING REMARKS

The importance of representation of urban data is clear in the effective design and management or urban systems. However, the increasing quantity and complexity of this data is placing immense pressure on existing visualisation techniques. By supporting information visualisation with audio, the SUM tool hopes to relieve the visual burden of information overload. By appealing to the ears, it also hopes to reveal relationships which would otherwise not have been seen. Integrating space and time, it provides a more time-based tool for spatial design. Last but not least, it hopes to improve communication and participation within the decision-making process. Beyond the domain of urbanism, the SUM tool can be applied to other complex spatial systems, representing more than just the sum of their individual parts but the spatio-temporal relationships between them.

Acknowledgments:

Mika Kuuskankare, Sibelius Academy, IRCAM, on the development of the SUM tool.

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SUM: from Image-based Sonification to Computer-aided Composition

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Abstract. This paper will discuss the development of the SUM tool, a user library with a graphical user interface within the computer-aided composition environment of PWGL, aimed at the integration of image and sound. We will discuss its internal structure, consisting of image layers, mappers, and paths. We will explain the mapping process, from the retrieval of graphic data to its translation into audio parameters. Finally, we will discuss the possible applications of SUM in both image sonification and computer-aided composition, resulting from this structure.

Keywords: image sonification, graphical computer-aided composition, open graphic score, structure

1 Introducing the SUM Tool

The SUM tool allows the integration of image and sound through a graphic user interface. It was originally developed as an audio-visual representation tool in urban planning [1], an applied discipline involving the spatial composition of temporal systems. The traditional use of multiple 2-dimensional graphic maps makes it difficult to represent dynamic flows, as well as synthesise multiple layers due to legibility constraints. Thus SUM provides a more temporal approach to spatial composition through sonification – the representation of data through auditory means [2].

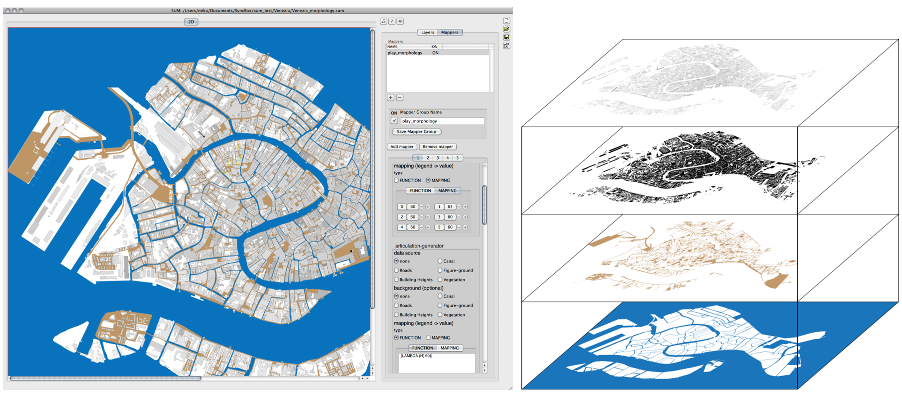

Fig. 1. The sonification of multiple urban maps in the SUM tool

Due to its design application, SUM supports both the importation and creation of multiple image layers (raster and vector) as data input. This data is then retrieved through the drawing of one or more vector paths over the areas of interest, and their graphic attributes mapped to sound attributes results in the generation of audio parts. Thus SUM supports a multi-dimensional spatio-temporal approach to image sonification, which sets it apart from other image sonification toolkits such as SonART [3].

As a user library within PWGL [4], a widely-used Lisp-based visual computer-aided composition environment, SUM can also be used as a graphical composition tool. PWGL's internal music notation editor strictly allows the description of object-based graphical scores [5], rather than the pixel-by-pixel exploration of a score as an image. Other graphical computer-aided composition environments, such as HighC [6] which is inspired by Xenakis' UPIC system [8], support the drawing of graphic objects but are limited to a single horizontal time axis. However SUM, with its ability to create and read objects along multiple spatio-temporal paths, allows an image to be composed and played as an open graphic score from multiple perspectives.

This paper will discuss the structure of SUM, which supports a multi-dimensional approach to both image sonification and graphical computer-aided composition.

2 The Structure of SUM

The SUM tool consists of three main components: images; paths; and mappers. The following section will explain each of these components and their inter-relationships.

2.1 Images

SUM uses images as data-sources. Each image is described by a 'color-key', in which each color of interest is allocated an arbitrary numerical value, to be referenced in the sonification mapping process. SUM supports the superimposition of multiple images, which allows the synthesis of overlapping graphic information, visualisable as a '3D' matrix of data as shown in figure 2. A group of data-sources is called a 'dataset', from which any number of image layers may be drawn upon as data-sources in the mapping process.

SUM allows the co-existence of raster and vector images. The flexibility of raster importation permits any visualization, including that produced by other software, to be sonified. The tool's vector drawing ability allows it to be used as a computer-aided design tool, such as Adobe Illustrator or AutoCAD, with graphic changes able to be made internally.

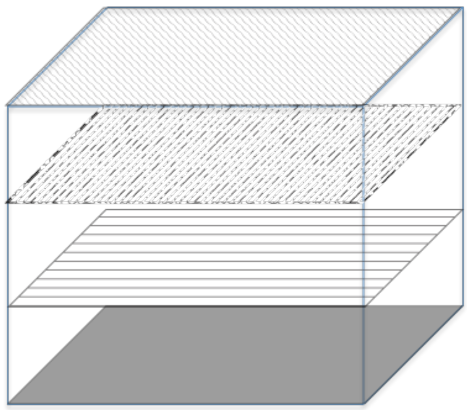

Fig. 2. Visualisation of a 'dataset' of 2D images as a 3D matrix

2.3 Paths

A path is responsible for defining the connection between the graphic space and musical time. It is a spatio-temporal object consisting of the following qualities: location; direction; delay; duration; and speed. The path is drawn as a vector polyline by the user over the area of interest, and then assigned a speed and delay. SUM supports the co-existence of multiple paths of various speeds and delays.

2.2 Mappers

A mapper is responsible for defining the sound output of the mapping process. It translates the graphic attributes retrieved from the image into discrete audio events, defining the sound attributes of pitch, volume, articulation and timbre. The definition of each sound attribute is independent of another. Thus one mapper can refer to multiple data-sources. A group of mappers is termed a 'mapper-group'.

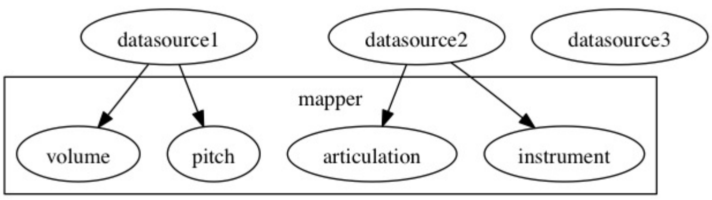

Fig. 2. The SUM mapper: one possible definition of sound attributes by data-source

3 The SUM Mapping Process

The SUM mapping process from image to sound is a two-fold process: graphic data is retrieved from a data-source by a path; it is then applied to a mapper for transformation into audio attributes.

3.1 Data Retrieval

The SUM mapping process is path-driven. Data is retrieved through the drawing of a vector path on an image, and the sampling of the image along this path. The vector path is rasterized according to Bresenham's line algorithm [9] in order to break it down into discrete sampling points, while retaining the order of the points to determine the direction of the path along which the time progresses. Thus for a line extending upwards and to the left, the pixels would be sampled in the order shown in figure 3.

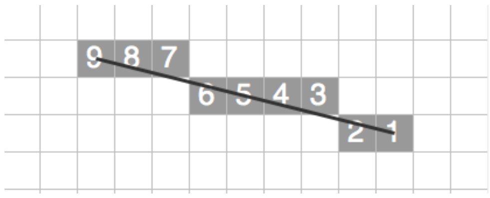

Fig. 3. Diagram of Bresenham's line algorithm, showing sampling order

Each raster map image is then sampled pixel-by-pixel to retrieve the data of interest per each sample-point along the path. The user-defined start-time and playback speed determines the temporal structure of the mapping process.

3.2 Parameter-Mapping

After retrieval of the graphic information along a path, these values can be applied to a mapper in order to generate the desired sound attributes of an acoustic signal (pitch, volume, articulation, and timbre). The parameter-mapping process is defined by assigning a legend, from a given data-source, with a sound value. This can be implemented either directly through the graphic user interface or by using Lisp for more complicated mappings.

Application of a path to a mapper produces a set of sound parameters, which can then be used to drive a wide-variety of internal or external instruments. PWGL has its own internal synthesizer as well as MIDI and OSC output. This allows connection to external sound synthesis engines such as Max/MSP and flexible possibilities for sound output.

It should be noted that a path and a mapper are independent of each other in terms of data-source/s. Thus different mappings can be generated from the same dataset of data-sources.

4 The SUM Compositional Process

This section will relate the SUM process to the compositional process. Here we introduce the concept of the SUM score, consisting of multiple SUM parts.

A SUM part is a sequence of audio events, the qualities of which are defined by the retrieval of data from an image with a path, and applying this path to a mapper. Thus the generation of a SUM part is a path-driven process. Application of multiple paths to one mapper will produce multiple SUM parts of the same timbral quality, but of variable temporal structure. Application of the same path to multiple mappers will produce multiple SUM parts of the same spatio-temporal quality, but of variable timbral qualities. Different combinations of paths and mappers allow the generation of numerous SUM parts from the same dataset. Figure 4 shows one possible network of paths and mappers producing a SUM score.

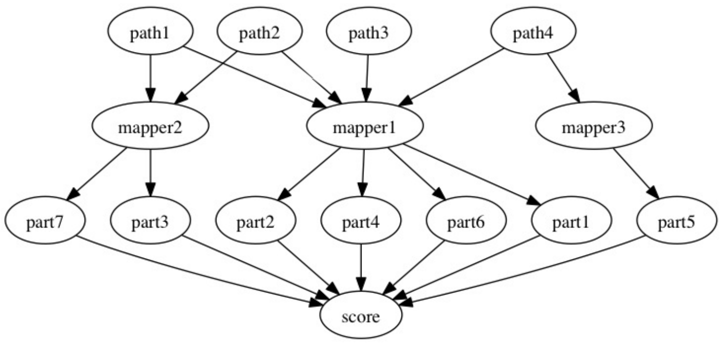

Fig. 4. An example of a SUM score - one possible network of paths and mappers

5. Applications

The flexibility of the mapping process established between image and sound has the potential for application in both image-based sonification and computer-aided composition.

5.1 Image Sonification – Playing of 'Visual Music'

The SUM tool, with its image-based input and user-defined mapping process, supports the sonification of any color-coded image. This means that any bitmap image can be sonified according to its own color-key.

One artistic application is in the playing of 'visual music' – the generation of musical concepts such as rhythm through graphic means. One visual composition technique is through the spatial arrangement of colour, as explored by Piet Mondrian in his series of paintings entitled 'Composition' utilizing the primary colours of red, yellow and blue. Here we demonstrate the sonification of his work *Woogie Broadway*

Boogie (1942-43), in which he attempted to express the musical rhythm of the 'boogie woogie' through colour, and in addition along a gridded structured resembling the streets of New York[10]. By separating the painting into each of its colours, and mapping each colour to a different sound parameter, such as pitch, volume or timbre, we can not only see but listen to this rhythm along each of the paths.

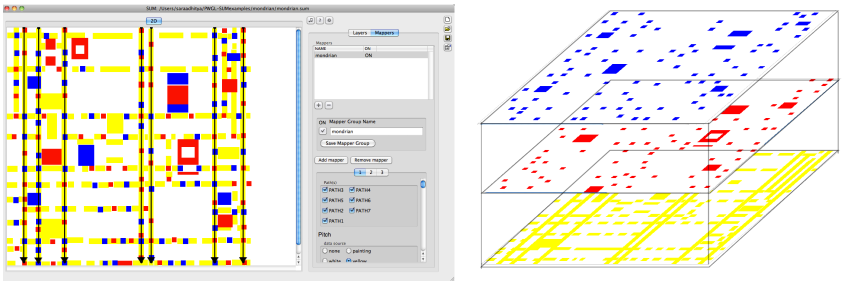

Fig. 5. Sonifying the colour rhythms of Mondrian's *Broadway Boogie Woogie* [10]

Through the sonification of such visual artworks in SUM, we can explore the application of visual composition techniques to musical composition. We can also see the potential for SUM to play any image as an open graphic score. In the following section, we will demonstrate the use of SUM as a tool for computer-aided composition, leading to the generation of a graphic score.

5.2 Computer-aided Composition – Generation of a Graphic Score

The SUM tool, with its vector drawing capability, also supports the creation of graphic scores. The user-defined mapping process means that a composer is free to create his own graphic-sound vocabulary. It supports the creation of a multi-layered graphic score (ie. multiple spatial dimensions), and its playback from any direction, time and speed (ie. multiple temporal dimensions).

As an example, we will show how the graphic score created by Rainer Wehinger for Gyorgy Ligeti's Artikulation, can be generated in SUM and used to explore its playback.

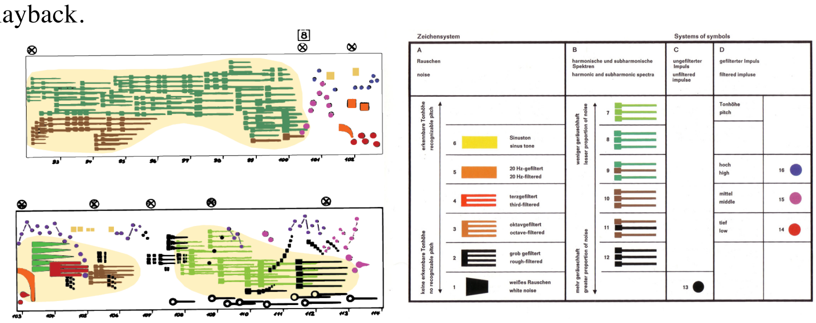

Fig. 6. A section of Wehinger's graphic score for Artikulation (Ligeti) with accompanying colour-coded legend [11]

Wehinger represented each of Ligeti's sound objects graphically, in terms of different forms and colors (see figure 9). As different colors are read as different sound objects in SUM, we can structure our SUM score similarly.

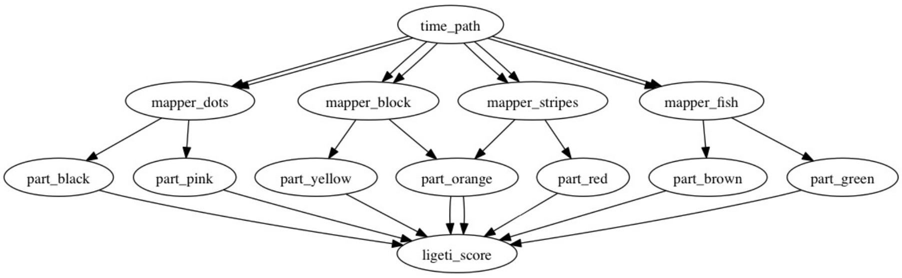

Fig. 7. A possible SUM score structure of Artikulation

The subsequent reading of our SUM score, by any number of user-defined spatio-temporal paths, frees it from its intended linear reading from left-to-right. As seen in figure 8, the same segment of Wehinger's score can be played from different directions and at different speeds.

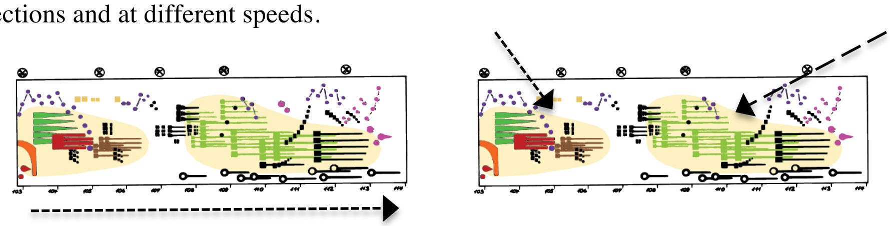

Fig. 8. Different ways of reading Artikulation – linearly as a pianoroll or as an open score

This opens up new possibilities for existing graphic scores to be played in alternative ways and to generate new musical results.

6. Conclusions

As seen above, the structure of the SUM tool supports the integration of image and sound in multiple spatial and temporal dimensions. Growing from the objective to sonify urban maps for a more temporal representation of urban systems, as seen in this paper, we can also use it to compose a multi-dimensional graphical musical score and play it back from numerous perspectives. The flexible structure of SUM allows the audio-visual representation of multiple spatio-temporal relationships in general, from an urban system to a musical score.

Future improvements include the automatisation of the retrieval of the image color palette, and thus the generation of the color-key. We also aim to improve our path-sampling approach in order to more accurately determine the duration of a path.

Acknowledgments.

The authors would like to thank IRCAM and CCRMA for their hospitality during this collaboration. The work of Sara Adhitya has been supported by the John Crampton Scholarship Trustees of Australia. The work of Mika Kuuskankare has been supported by the Academy of Finland (SA137619).

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10. Rainer Wehinger's graphic score (1969) for Gyorgy Ligeti's Artikulation (1958), http://www.tumblr.com/tagged/artikulation

COMPOSING GRAPHIC SCORES AND SONIFYING VISUAL MUSIC WITH THE SUM TOOL

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ABSTRACT

This paper will explore the potential for the SUM tool, intended initially for the sonification of images, as a tool for graphical computer-aided composition. As a user library with a graphical user interface within the computer-aided composition environment of PWGL, SUM has the potential to be used as a graphical approach towards computer-aided composition. Through the re-composition of the graphic score of Ligeti's Artikulation, we demonstrate how SUM can be used in the generation of a graphic score. Supporting spatio-temporal timepaths, we explore alternative ways of reading this score. Furthermore, we investigate the claim of certain visual artworks to be 'visual music', by sonifying them as graphic scores in SUM.

1. INTRODUCTION

The SUM tool [1] is a user library with a graphical user interface within the computer-aided composition environment of PWGL [2]. Initially designed for the sonification of images, through a user-defined mapping process, it also allows a graphical approach to computer-aided composition.

The field of graphic-based computer-aided composition spans from Xenakis' pioneering UPIC, to CAC software such as OpenMusic and PWGL, and image-sonification toolkits such as SonART [3]. However, the former was limited to piano-roll lecture, the second allows the description of object-based notation [4], and the third allows importation of images which can be read by raster-scanning or real-time probing.

SUM can be seen to span all three approaches, allowing both the pixel-by-pixel exploration of a score as an image, as well its temporal reading from any number of angles, and the ability to generate images internally. It also supports the use of multiple time paths, allowing the lecture of the image in numerous ways – as the open graphic score was intended.

Thus this paper will explore the use of the SUM tool in the computer-aided composition of graphic scores. We will first present an overview of the structure of the SUM tool and its relationship to the traditional compositional process. Then we demonstrate how a graphic score can be composed in SUM through the recomposition of Rainer Wehinger's representation of Ligeti's Artikulation. We then demonstrate the ability of SUM to modify and play this piece in multiple ways, before attempting to play selected artworks as graphical scores through the process of image sonification. Thus we hope to demonstrate the potential of this tool to be used as a flexible graphical approach to composition.

2. SPATIO-TEMPORAL ORGANIZATION

The following section outlines the definition of space and time in SUM through the definition of its component elements of image layers and time paths.

2.1 Spatial structure

In SUM, images are used as musical 'data-sources'. Raster images can be imported, and the spatial scale depends on the resolution of the image in dpi. Vector objects can also be created within the tool. SUM supports the superimposition of multiple images, which can be seen to form a 3D matrix. This layered structure of image data-sources can be seen as the equivalent of simultaneous parts. Images can either be read independently or in combination with each other.

2.2 Temporal structure

The temporal structure of SUM is path-based, user-defined by the drawing of a vector path and its application to one or more images. The path samples the image(s) according to Bresenham's line algorithm, as shown in figure 1 [5].

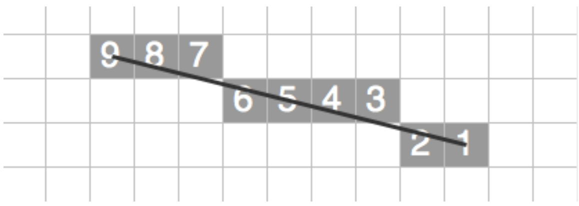

Figure 1. Diagram of Bresenham's line algorithm, showing sampling order

The user defines the start-time and speed of a path, which then determines the sampling rate and thus the timing of the score.

Multiple paths are supported, allowing the score to be read from different spatial directions, like an open graphic score. Since they each have there own independent start-times and speeds, it is possible to read an image at the same or different speeds, allowing the user to flexibly manage the time of a composition.

Thus through the combination of multiple image layers and spatio-temporal time paths, SUM can be seen to support the creation of a multi-dimensional graphic score.

3. GRAPHIC MAPPING PROCESS

In a graphic score, sound is often represented through non-traditional symbols or images. With its ability to import raster images as well as create vector graphics, SUM becomes a flexible tool for composers to develop their own graphical notation. This is implemented through the definition of one or more mappers.

A mapper translates the color attributes retrieved from the image into audio events, defining the sound attributes of pitch, volume, articulation and timbre. A group of mappers is termed a 'mapper-group'.

The parameter-mapping process is defined through the mapping menu of the graphic user interface (figure 3). The composer selects the data-source to be used and assigns each legend value with a sound value (in MIDI units). This can be implemented by directly inputting the values for each legend value in the GUI, or by using Lisp for more complicated mappings. There is also the option to output the data through OSC for further mapping in an external program such as MaxMSP or PureData.

As the definition of each sound attribute (pitch, duration, volume, timbre) is independent of another, any combination of images can be used to define one sound. Thus one mapper can refer to multiple data-sources and different mappings can be generated from the same dataset of data-sources. This gives a composer much freedom in defining the relationship between image and sound, and developing his or her own graphic notation.

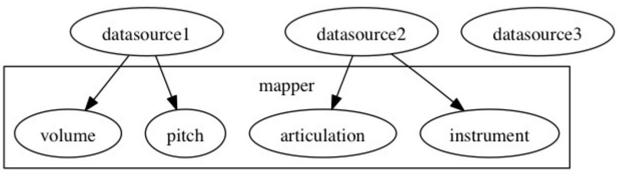

Figure 2. The SUM mapper: one possible definition of sound attributes by data-source

Mapper-groups can be activated and disactivated so that any combination can be used to create a SUM score, to be explained in the following section.

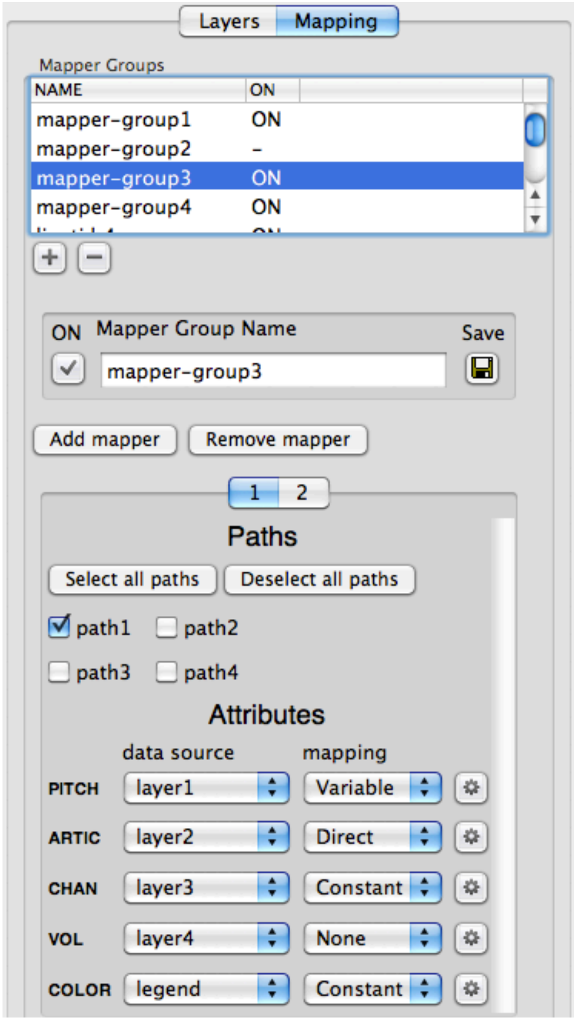

Figure 3. Mapping menu of the graphic user interface

4. SUM COMPOSITIONAL STRUCTURE

As a part of the compositional process, a 'SUM score' is generated consisting of any number of parts. Here a 'SUM part' is the result of the application of a path to an image data-source via a mapper. The resulting compositional framework can thus be represented as a network of paths and mappers, as shown in figure 4.

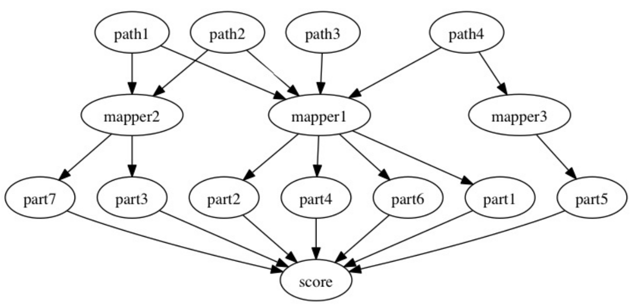

Figure 4. An example of a SUM score - one possible network of paths and mappers

5. CREATION OF A GRAPHIC SCORE

This section will demonstrate how a graphic score can be created in SUM through the use of an image data-source. As an example we will ‘recompose’ Rainer Wehinger’s graphic representation of Gyorgy Ligeti’s Artikulation, developed 12 years after the work’s initial composition in 1958. Wehinger represented Ligeti’s various sound objects graphically by using different forms and colors according to the legend shown in figure 5.

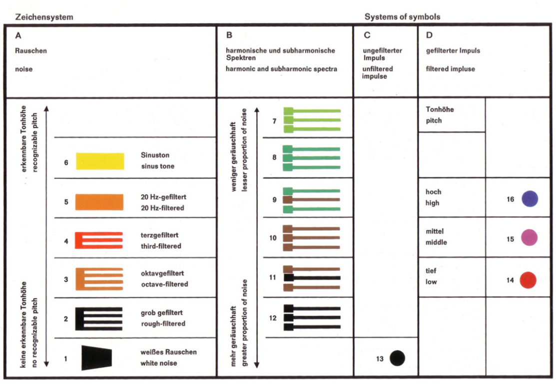

Figure 5. Legend of sound objects in Artikulation [5]

Since sound in SUM is defined through the use of color, we can easily import this graphic score and ‘play’ it through the definition of a color-key. In order to retain the identity of overlapping objects, we have separated the score into color-coded layers. This can be represented as a matrix of superimposed 2D layers as shown in figure 6.

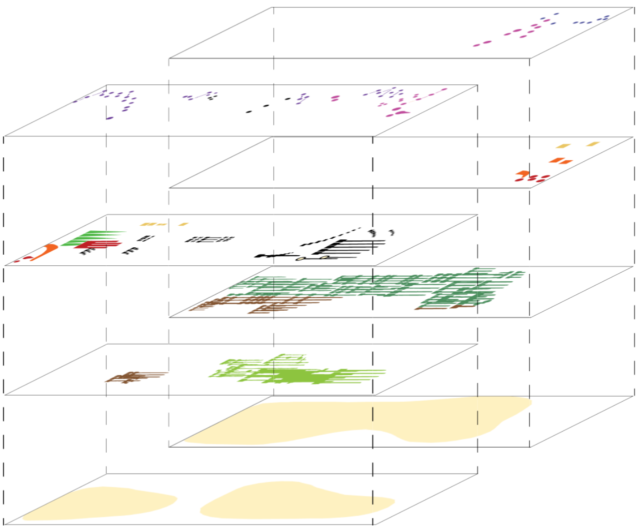

Figure 6. Representation of the different sound objects in an excerpt of Artikulation into color-coded layers, represented as a 3D matrix

6. PLAYING GRAPHIC SCORES IN SUM

As explained earlier, SUM supports the co-existence of multiple paths at differing speeds, and thus the playing of an image as an open graphic score. Here we give examples of the different ways in which our ‘recomposed’ graphic score of Ligeti’s Artikulation can now be played, as shown in figure 7.

The top of the score shows how the score can be played in the intended traditional piano-roll style by drawing the paths from left to right over the objects of interest.

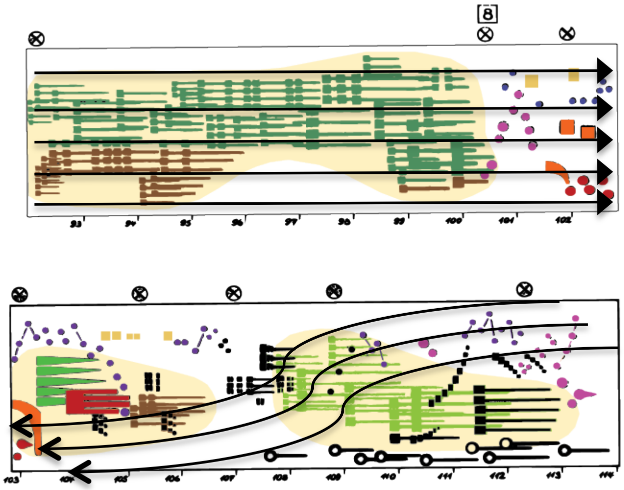

Figure 7. Alternative readings of Ligeti’s Artikulation by paths approaching from different spatial directions [6]

However, as the temporal structure of a SUM score is not restricted to one axis, we can also approach the reading of the score from any direction, for example with a curved path in reverse, as shown at the bottom of figure 7. Since the timing of the score is determined by the start-time and speed of each path, as defined by the user, these paths can be either synchronized or not. The composer can thus play a composition at multiple speeds.

7. GRAPHICAL TRANSFORMATIONS

Here we explore the possibility to create new image layers in SUM to apply graphic transformations to an existing graphic score. Through image masking and graphic filtering we can add sound objects or alter audio parameters.

7.1 Image masking

SUM allows the option of masking one image with another. With its internal vector drawing ability, new graphic objects can thus be drawn over an existing score in SUM with the effect of modifying its sonic output.

This masking ability can be used to subtract areas of the score by returning them to their background color. In the top of figure 8, we have added an extra layer of white rectangles, in order to visually ‘erase’ existing sound objects. New objects can also be added to conceal existing objects, such as the black triangles at the bottom of the score.

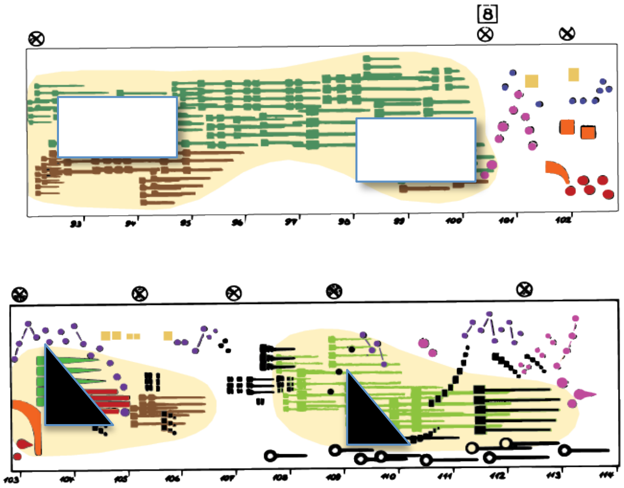

Figure 8. Alteration of Artikulation using the vector object creation and masking functions of SUM

7.2 Graphic filters

Graphical filters can also be created to globally control a sonic parameter over an existing score, for example its overall volume or timbre. This is implemented by parameter-mapping the filter layer to the audio parameter concerned, as seen in figure 9 in which the superposition of a gray-scale gradient globally reduces the volume from left to right across the score.

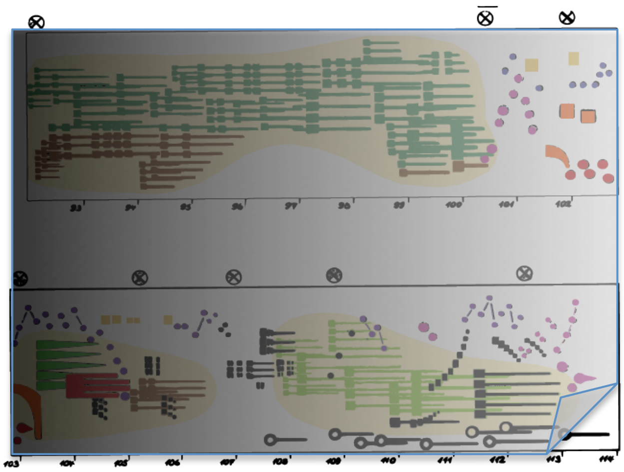

Figure 9. Application of a separate graphic layer to globally control an audio parameter such as volume

8. PLAYING 'VISUAL MUSIC'

This section will explore the application of SUM to the visual arts, in particular the 'visual music' of Wassily Kandinsky [7] and the color compositions of Piet Mondrian. By importing these 'musical' paintings as raster images into SUM, we can explore these ideas sonically.

8.1 The musical lines of Kandinsky

Many artists have explored the line as the primary element of movement, most notably Wassily Kandinsky in his book [8]. In SUM we can explore the potential for such line drawings to be used for the structuring of time in a graphic score. We have used the line study by Kandinsky, seen in figure 10, as a basis for our path-based approach to image-reading.

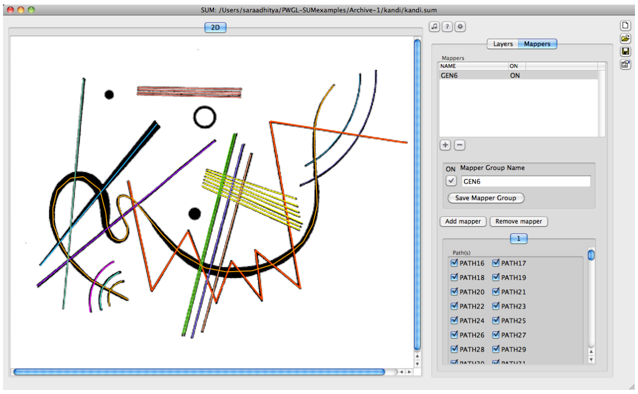

Figure 10. A varied combination of image-reading paths in SUM, based on a line composition by Kandinsky [9]

Here we mapped the lines to the harmonic series in terms of their y position over time. The resulting 'musical lines' can be seen in the color-coded piano roll of figure 11.

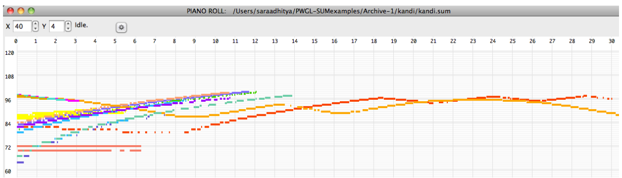

Figure 11. The generated color-coded piano-roll of Kandinsky's line study mapped to a harmonic series [9]

8.2 The color compositions of Mondrian

Composition of color in space is another basic technique of generating visual rhythm. Piet Mondrian produced a series of paintings entitled 'Composition', in which he explored the spatial composition of the primary colors of red, blue and yellow. In his painting *Broadway Boogie Woogie* (1942-43), he intended to express the rhythm of the 'boogie woogie' through the organization of these colors along a gridded structure resembling the streets of New York [10]. By mapping each of these colors to different percussion sounds in SUM, and drawing paths of movement over the areas of interest, we were able to listen to the rhythmic results (figures 12 and 13).

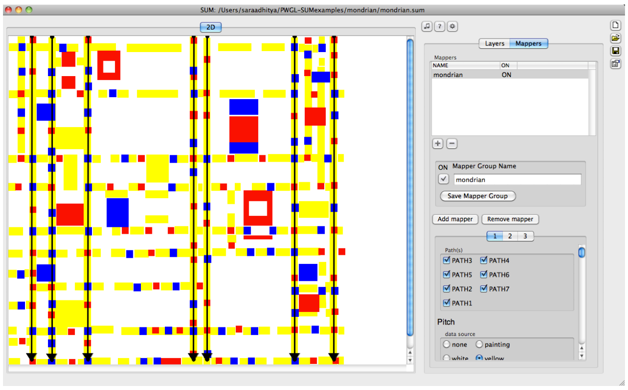

Figure 12. Playing the colored rhythms of Mondrian's *Broadway Boogie Woogie* [10] in SUM

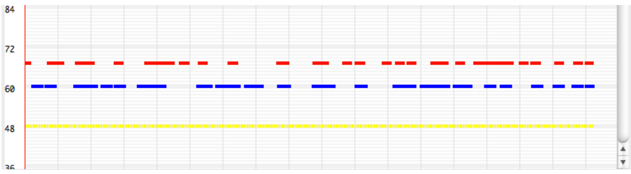

Figure 13. The mapping of colors to tuned percussion instruments and the color-coded piano-roll generated

9. CONCLUSIONS

In this paper we have explored the potential of the image sonification application of the SUM tool as a more graphical approach to computer-aided composition. With its flexible structure of multiple data-sources, paths and mappers, the generation of numerous combinations of parts, and thus scores, is possible. The structuring of time along user-drawn spatio-temporal paths allows an image to be read from a multitude of directions like an open graphic score, and alternative readings easily proposed and tested.

As seen in the examples presented above, the musical results are as varied as the images and mappings themselves. In the future we will explore different mappings, particularly in terms of timbre through instrumentation or sound synthesis, in order to generate a more effective image-sound vocabulary for the interpretation of each image.

What can be seen so far is the potential of the SUM tool as a means of exploring the relationships between compositional techniques in the visual arts and those in music. Drawing such audio-visual connections can only inspire new compositional techniques in music and generate a more multi-sensorial approach to music composition.

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THE SUM TOOL AS A VISUAL CONTROLLER FOR IMAGE-BASED SOUND SYNTHESIS

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ABSTRACT

This paper presents an image-based system for the algorithmic control of sound synthesis. Our system allows for the superimposing of multiple spatio-temporal trajectories (paths) on top of layered images. The color data retrieved from the images can be converted into, and interpreted as, control information for controlling the parameters of a synthesis algorithm.

The work is conducted within the PWGL visual programming environment, within which we have developed a new user-library called SUM. The SUM tool is aimed at the integration of image and sound and was originally developed for the sonification of urban maps and the analysis of urban structure.

Lately, SUM has been developed towards a more general image-based compositional tool. Unlike most image-to-sound toolkits, which are limited to a single horizontal time axis, SUM allows for the access of the image data from multiple, user-definable spatio-temporal perspectives and the mixing of both vector and raster images.

In this paper, as a purely technical example, we build an image-based 'mixer' to control the parameters of a granular synthesizer. Granular synthesis has a long history in the field of computer music and it is frequently used as both a synthesis technique and a compositional method.

1. INTRODUCTION AND BACKGROUND

In this paper, an image-based data mapping scheme for controlling sound synthesis is presented. The scheme originates from the data sonification tool SUM[3]. SUM is a PWGL[5] user-library, aimed at the integration of image and sound, and originally developed as a tool for urban structural analysis.

Image sonification is currently an active research field and of interest from both scientific and artistic perspectives. There are several systems that aim specifically at image-to-sound translation. HighC[1] and Iannix[2] can be seen as attempts to revitalize Xenakis' UPIC system. HighC provides the users with a traditional piano roll representation and allows the drawing of curves, lines, and other geometric objects. Other image-based audio software include, for example, Audiopaint and MetaSynth. Audiopaint is essentially an additive synthesizer which transforms the pixel information retrieved from the image to frequency, time, and amplitude. However, it does not offer any editing tools. Metasynth is arguably one of the most comprehensive software packages in its class, providing its users with filters, spectral analysis, effects, a sequence editor, and a timeline editor for large-scale structural organization. Furthermore, AudioSculpt can also be considered an image sonification application but with functionality limited only to the sonification of spectral sonograms. Finally, SonART[12] is an open, network-based image sonification framework. The data retrieved from images is transmitted through OSC and can be used for synthesis in, for example, MaxMSP and Pd.

When translating information between the visual and auditory domains, the problem of representing and organizing time needs to be addressed. Most of the aforementioned applications are limited to a single horizontal time axis. However, SUM allows us to access the images from multiple spatio-temporal perspectives by superimposing a vector polyline over the areas (i.e., data) of interest.

Most of the toolkits also operate on raster images exclusively and do not support the creation of graphical information within the tool itself. SUM, however, allows the co-existence of both raster and vector images. It supports the superimposition of multiple images, arranged in layers like a 3D matrix of data, which allows for the synthesis of spatially-concurrent graphic information. The images can also be used to mask each other, covering parts of other images, allowing the selective use and alteration of an image without its direct transformation. Thus SUM allows the multi-layered composition of user-definable images, which can potentially be played as open graphical scores.

SUM can generate MIDI output and it can be connected to external sound sources through OSC[10]. In this paper, the data mapping scheme of the SUM tool is adapted to synthesis control. We use the information, generated by the SUM tool, to control the low-level DSP parameters of a synthesis process defined with the help of PWGLSynth[6]. Here, we have chosen a rather unorthodox approach, where we create 'an image of a mixer' from which we retrieve the control information. Due to our path animation scheme, we are also able to simulate the movement of the controls synchronized with the sound.

2. THE SUM APPLICATION

Most image-to-sound toolkits approach the sonification process through different scanning methods, usually restricted to left-to-right scanning. However, for compositional purposes a more flexible representation of time is needed. In this respect, the major contribution of the SUM tool in this respect is its ability to superimpose, over one or more images, an arbitrary number of paths. These paths are spatio-temporal objects which define the connection between the graphical and musical spaces. In addition to time and location, paths define, among others, direction, delay, duration, and speed. SUM supports the co-existence of multiple paths each having their own internal temporal properties.

2.1. SUM Graphical User Interface

Figure 1 shows the SUM user interface. Internally, there are two layers: an image layer; and a path layer. In the given example, we use gray-scale images. The image layer is composed of three different transparent (PNG) images: (a) the 'spatializer controller', drawn as a circle with gradient color; (b) the 'slider controllers', consisting of four rectangles with a gradient from black to white; and (c) the 'textural controller', displayed at the top of the figure.

The path layer consists of seven individual paths which model the desired motion profiles of the controllers as a function of time (much like in the case of servo-based mixers). For example, the temporal behavior of the grain duration can be defined graphically by superimposing a path on top of one of the 'slider controllers'. In our example, the paths travel in both directions. Here, all points of the path lie on the same vertical line making editing the paths inconvenient. However, as shown in Figure 2, the paths can also be displayed and edited as breakpoint functions, thus allowing us to define the movement of our imaginary controls more easily.

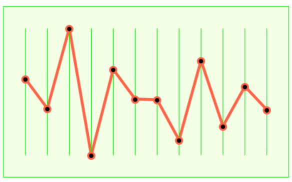


Figure 2. *The paths can be edited in a breakpoint function mode, facilitating the definition of points which lie parallel to either of the two axes.*

While the example shown is purely technical, the principle of image-based retrieval of control parameters can also be applied to more artistic applications. This may involve any number and combination of image layers, and the user is free to define the relationship between image and sound.

2.2. SUM Sonification Process

The SUM sonification process is represented in Figure 3. Multiple paths can access the image data. The paths are rasterized according to the Bresenham line algorithm[4] to produce a list of discrete data-points (the paths are single pixel wide). A mapper is then applied to each of the paths to transform the raw data into discrete or continuous control events. The same mapper can be applied to multiple paths, in which case, events of the same timbral quality, but of variable temporal quality will be generated. Conversely, application of the same path to multiple mappers will produce events of the same spatio-temporal quality, but of variable timbral quality. The mappers provide us with two ways of transforming the image data into discrete or continuous control events:

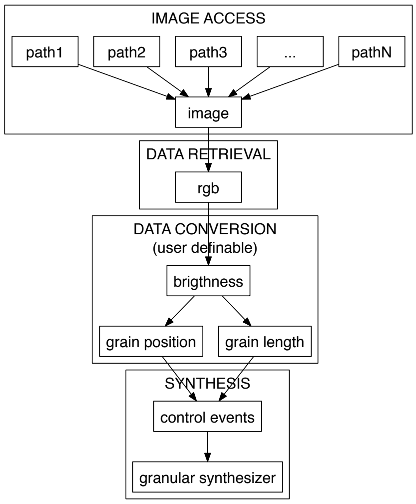


Figure 3. *The SUM sonification process: Multiple paths are applied to an image, producing a stream of RGB color values. The color values are then converted into discrete or continuous events and used as control information for a DSP algorithm.*

(1) using one-to-one mapping, i.e., there is one user value corresponding to each RGB color value, or

(2) using an arbitrary transfer function, which allows for the access and treatment of all the attributes contained by a data-point, e.g., RGB color value, time, duration, speed, spatial coordinates, etc.

3. SYNTHESIS CONTROL

In this section we give a brief example utilizing the SUM application shown in Figure 1. We aim to use the images as controllers to generate control information for a granular synthesis instrument realized with the help of PWGLSynth. Granular synthesis is an established sound synthesis method that creates sounds or sound textures from small segments of sound. These segments are called grains and they are usually below 100ms in duration. A typical granular synthesizer might allow the superpositioning of multiple grains and their playback at different speeds. By varying the waveform, envelope, duration, spatial position, and density of the grains, different sounds and sound textures can be created.

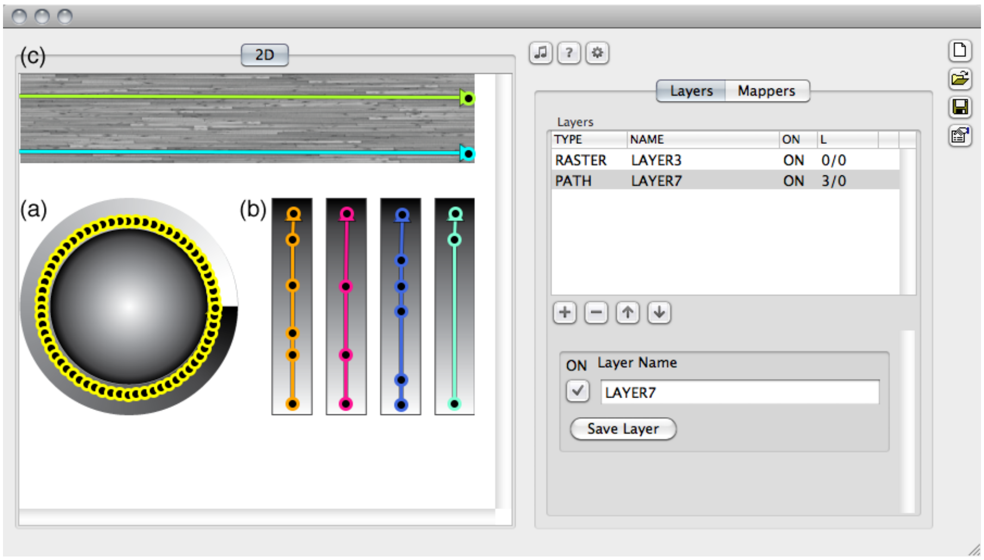


Figure 1. *The SUM interface showing two layers: a raster layer and a path layer. The raster layer contains some image-based controllers (a–c) and the path layer, in turn, contains paths which define the temporal behavior of the controllers.*

In the given example, the disk-shaped object (a) is used to control spatialization. The gradient colors (normalized between 0.0–1.0) are converted into angles (in degrees) and used as an input for a VBAP-based[7] spatializer. The four sliders can then be used to control parameters such as grain duration and master volume. Finally, the textured image (c) is used as a structural controller: the image is read from left to right and the color information is used to control the width of the window inside which the grains are randomly chosen.

3.1. The Synthesis Patch

The main PWGLSynth patch is shown in Figure 4(a). It defines the interface between SUM and PWGLSynth. The box named "grain_player" is used to receive the information sent by the SUM player. Here, we use the internal real-time message dispatching scheme of PWGL, where SUM sends pitch, velocity, and duration information through the box, which then interprets the incoming data and converts it into synthesis control information. The actual granular synthesizer definition is shown in Figure 4(b). Here, the real-time inlets, marked as ':start', ':end', and ':len', are shown. During playback, SUM sends, through the "grain player" box, the appropriate control information to these inlets which, in turn, change the parameters of the synthesis algorithm in real-time.

3.2. SUM Playback/Animation

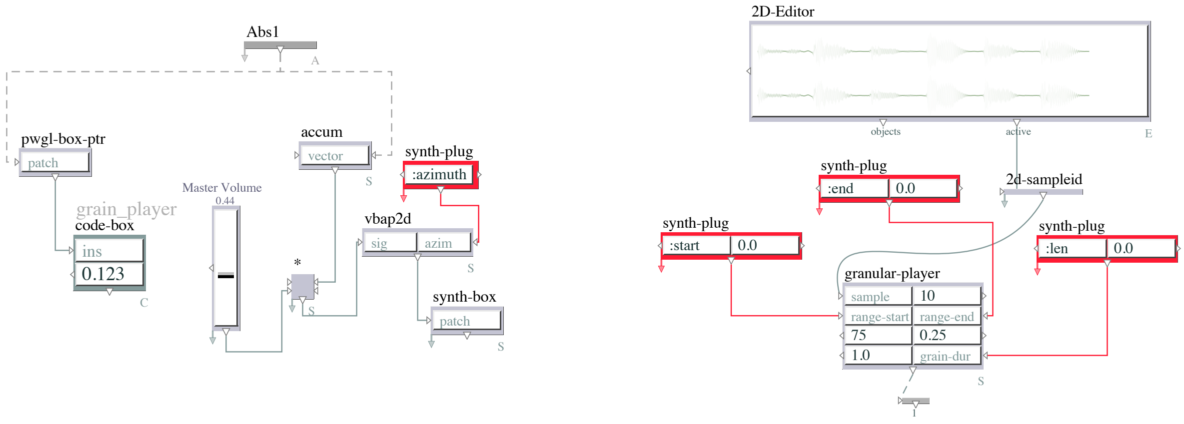
SUM provides image-to-sound synchronization during the playback. It animates the pertinent points along the given paths, thus making it possible to follow the 'graphical score' and verify the relationship between the image and the resulting sound. Furthermore, the points can be given a custom appearance. Here, we use rectangular shapes when animating the 'slider' paths, a loudspeaker-like image for the spatializer path, and a vertical 'playback line' for the rest.

4. CONCLUSIONS AND FUTURE WORK

Our preliminary experiments with image-based synthesis control are presented. The SUM tool, a PWGL user-library developed originally for the sonification of urban maps, is here extended to allow for synthesis control. We implement a simple image-based controller application that consists of traditional controllers using a disk-shaped spatialization controller, and a textured image for a more 'artistic' controller source.

Future improvements include more accurate and customizable path handling. First, we will define intelligent (meta)path classes that are able to access the image using different predefined methods, such as left-to-right scanning, circular scanning, and potentially also raster scanning[11]. Second, we aim to improve our path-sampling algorithms to allow for better timing and synchronization. For example, it should be possible to attach a tempo function to a path. Third, the paths should be able to send messages to each other, for example, to initiate playback. Fourth, we should allow for the mapping of the image data to arbitrary parameters. Due to SUM's original MIDI-centric approach, we currently support only pitch, duration, velocity, and channel (and also color for visualization). Fifth, we need to implement more elaborate elementary path types, e.g., based on Bézier curves, and also allow for the definition of arbitrary algorithmic paths.

All the code related to the raw image access and path handling (e.g., rasterization) should eventually find its way to an external open-source library written in C or C++. This would allow for the use of the data in other applications and it would eventually allow for the scripting of SUM.



(a) (b)

Figure 4. *The main SUM instrument patch (a) containing the granular player implementation Abs1, details of which are shown in (b), the real-time controller box (grain_player) a master volume slider, the spatializer box (vbap2D) with the real-time entry point ':azimuth', and the synth-box (i.e., 'dac'). The granular synthesis patch (b) contains the input sound sample, the granular player box, and the real-time entry points for the control data, marked as ':start', ':end', and ':len' respectively.*

Finally, we are actively researching the possibilities of native 3D formats and we are also in the process of moving from proprietary 2D graphics API to OpenGL[9]. The development of an .obj[8] format importer is on the way and would eventually allow us to create and experiment with natively multidimensional graphical scores.

Acknowledgements

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FROM MUSICAL SCORE TO GRAPHIC PLAN: THE DEVELOPMENT OF SUM AS A DESIGN TOOL

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ABSTRACT

This paper presents the latest developments of the SUM tool, aimed at the integration of image and sound. A user library within the PWGL visual programming environment, it allows both image sonification and graphical computer-aided composition. Initially developed for the sonification of graphic urban maps, in which MIDI data is generated from graphics, the SUM process can now be reversed, with MIDI being the generator of the graphics themselves. We present three new developments which allow this: the ability to import MIDI into SUM to generate spatio-temporal vector time-paths; the ability to access the temporal structure of these paths through its points; and the ability to draw vector objects and develop a custom-made object library. These functions will allow us to generate graphics from music, which may form the basis of future works of 'visual music' as well as the musical-generation of graphical designs.

1. INTRODUCTION

The SUM tool [1] is a user library with a graphical user interface within the computer-aided composition environment of PWGL [2]. Initially designed for the sonification of images, through a user-defined mapping process, it also allows a graphical approach to computer-aided composition. [3]

The field of graphic-based computer-aided composition spans from Xenakis' pioneering UPIC, to CAC software such as OpenMusic and PWGL, and image sonification toolkits such as SonART [4]. However, the former was limited to piano-roll lecture, the second allows the description of object-based notation [5], and the third permits the scanning and exploration of imported raster images.

SUM combines all three approaches to allow both the pixel-by-pixel exploration of a score as an image, its temporal reading from any number of angles, and the ability to generate images internally. It also supports the use of multiple time paths, allowing the lecture of the image from different perspectives.

Previously, we have explored the use of this multi-dimensional spatio-temporal structure in the computer-aided composition of graphic scores. In this paper, we explore how SUM can be used as a graphic composition tool in the design field.

After first presenting an overview of the existing structure of the SUM tool, we introduce its three latest developments in light of this structure: the ability to import MIDI files as vector paths; the ability to access the temporal structure via the individual points on a path; and the ability to draw objects 'freehand' and create a library of custom-designed shapes.

In order to demonstrate how these new functions allow the 'musical' generation of a graphic composition, we apply it to an urban design project. By importing a MIDI file of interest, we use SUM to visualize the temporal structure of the music, allowing its direct application in design, or as a basis for design development.

Thus in this paper, we explore the SUM tool as a temporal approach to graphical design.

2. EXISTING STRUCTURE

In this section we outline the existing spatio-temporal structure of SUM, consisting of multiple image layers and vector time paths.

2.1. Timing in SUM

When translating information between the visual and auditory domains, the structuring of time needs to be addressed. Most sonification tools are limited to a single horizontal time axis, in the style of a piano-roll. However, SUM allows us to access the images from any direction and at any speed through the drawing of a vector polyline over the image(s). Through its subsequent application in the mapping process, the path samples the image(s) according to Bresenham's line algorithm [6].

2.2. Images in SUM

SUM allows the co-existence of both raster and vector images. It also supports the layering of multiple images, allowing them to be played simultaneously, even when covering one another. Thus we can compose multi-layered graphic compositions, from both existing images and new vector objects.

In SUM, images are used as musical 'data-sources'. Raster images can be imported, and the spatial scale depends on the resolution of the image in dpi. Vector objects can also be created within the tool. SUM supports the superimposition of multiple images, which can be seen to form a 3D matrix. This layered structure of image data-sources can be seen as the equivalent of simultaneous parts. Images can either be read independently or in combination with each other.

2.3. A multi-dimensional structure

Through the combination of multiple image layers and vector time paths, SUM can be seen to support the composition of multi-dimensional spatio-temporal structures. Previously used to compose graphical musical scores, it is equally adapted to the composition of temporal graphical designs. Based on this structure, in the following section we will explain the implementation of SUM's latest developments.

3. IMPLEMENTATION

The new developments to SUM allow greater flexibility to manipulate this spatio-temporal structure through the ability to: 1) import a MIDI file as a time path; 2) access the temporal structure of a path through its individual points; and 3) create custom vector shapes by 'freehand' drawing using an Object Illustrator.

3.1. MIDI Importation

A standard MIDI file can be imported as a path layer. The MIDI tracks are converted into paths and each event in the track is converted into a point. The points have default spatial positions that are calculated according to the start times of the associated MIDI events. The time resolution, i.e. pixels per second, can be defined by the user. By default, the events are arranged along a straight horizontal line to ensure synchronization between the tracks.

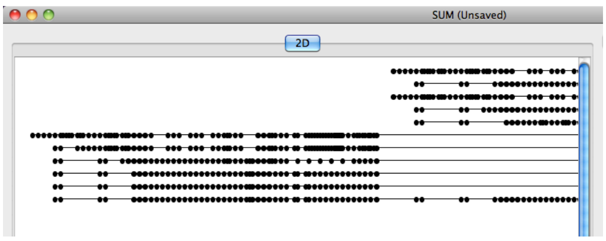

Figure 1. The importation of a standard MIDI file as vector paths in SUM, with each track as an individual path

MIDI paths are sonified in the same way as normal paths. The line between the points is rasterized, which defines the duration of the event attached to that point. The subsequent points are also shifted in time.

3.2. Temporal Points

Previously, the paths were traversed by SUM in their entirety and at a constant speed. The speed could be assigned to each path, either defined spatially - in metres or kilometres per second – or temporally, such as the beats per second used in music. However, the temporal structure of a path could not be altered within itself.

Now, SUM supports additional point types that can be used to control the rasterization process. Every point can now be assigned an individual speed, which determines the speed of the line segment immediately following. Thus individual line segments of the same path can now be assigned different speeds.

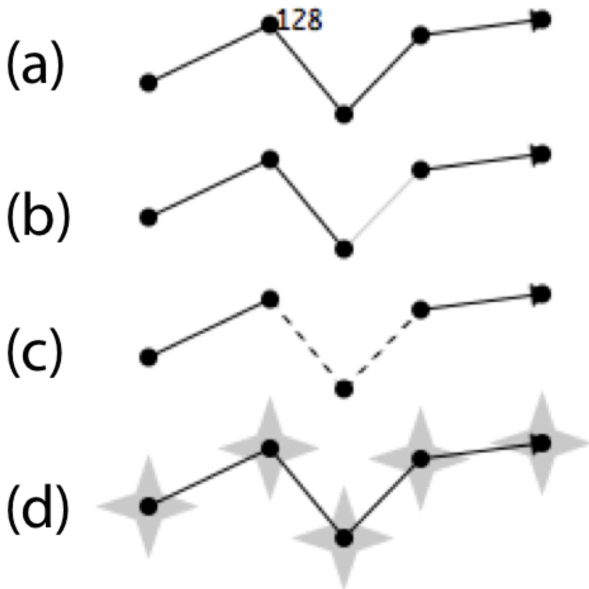

Figure 2. The ability to manipulate individual points of a vector time path

Figure 2 demonstrates four new point functions.

In Figure 2 (a) the speed of the second line segment is set to 128 units. The definite speed of the line segment depends on the speed unit of the enclosing path. The points not showing speed values use the default speed set by the path.

Figure 2 (b) shows the ability of points to be silenced. The line segment following a silenced point consumes the same amount of time as a normal line segment but produces no sound. A silenced line segment is represented as faded.

The points can also be made 'discrete', which means that the following line segment is not rasterized at all. A discrete point skips the subsequent line segment and playback is resumed from the next non-discrete point onwards. These skipped line-segments are shown in Figure 2 (c) as dashed lines.

Finally, each point can be assigned an individual shape, as shown in Figure 2 (d). The shapes are displayed instead of the standard point. Custom shapes can be created using the SUM vector object Illustrator.

3.3. Object Illustrator

SUM has a built-in llustrator, which allows for the user-definition of vector objects. The SUM Object Illustrator is a drawing tool that can be used to create open or closed polygons. Open polygons are generally used as paths. The shapes can be drawn using either a freehand mode or by inputting discrete points, as well as using a combination of both. A finished shape can be modified through the 'point selection mode', which allows the point handles to be manipulated by dragging. If more precise manipulation is needed, a single control point handle can be selected and repositioned by entering the exact coordinate values.

The vector objects created within the SUM Object llustrator can be individually moved, resized, and modified. They can also be copied or pasted. The line thickness, color and position of each object are defined when applied to a SUM vector layer.

Furthermore, the vector objects can also be defined algorithmically. This allows for the definition of shapes/paths that are difficult to draw by hand, such as, circles or bezier curves. Every aspect of the points in the shape, in addition to the coordinates, can be controlled algorithmically.

The vector objects can then be saved with the active project or they can be saved as global shapes making them accessible from any SUM project. Thus a SUM Object Library can be developed by the user.

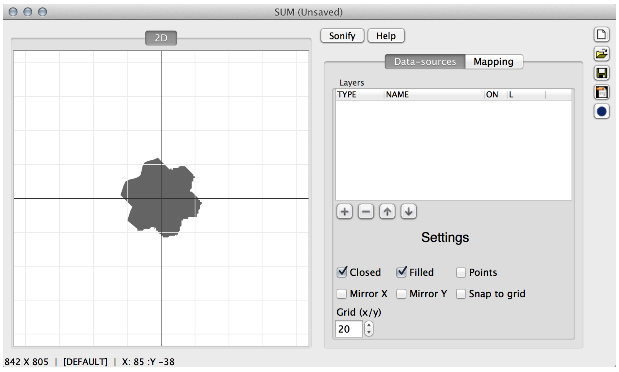

Figure 3. A tree object created in the Object Illustrator and saved to its Object Library for later usage (see Figure 7)

Using the Object llustrator option panel (Figure 3), several options can be selected.

a) A mirror symmetry mode can be used to define vector objects that are symmetrical on either the x or y axes.

b) A background grid can be displayed to aid with both scaling and drawing. The size of the grid can be user-defined. By selecting the 'snap-to-grid' option, the points can be automatically aligned to the nearest grid intersection. Grid alignment can also be applied afterwards to the whole shape or to a selection of points.

A line simplification algorithm can also be applied to the object. Currently, we use two simplification methods. The simpler of the two just reduces the number of points in the shape by half, i.e., every second point is removed. The second algorithm is implemented using the Ramer-Douglas-Peucker line simplification algorithm. [6]

c) Finally, the Illustrator view can also be used as an overlay, i.e., it can be displayed on top of one or more SUM graphical layers. This allows for the drawing of objects to scale, or for the accurate placement of a path or object to an image.

4. APPLICATION TO DESIGN

In order to demonstrate the use of SUM as a design tool, here we apply it to an urban design project. We use the MIDI file of a piece of music to compose urban design elements along selected paths of interest, and thus inform the urban experience along them.

4.1. Raster image and Vector path

First, a raster image of the site was imported, and the path of interest drawn as vector paths. One path is drawn along the road, shown in dark green, while the other is to be generated within the park (light green).

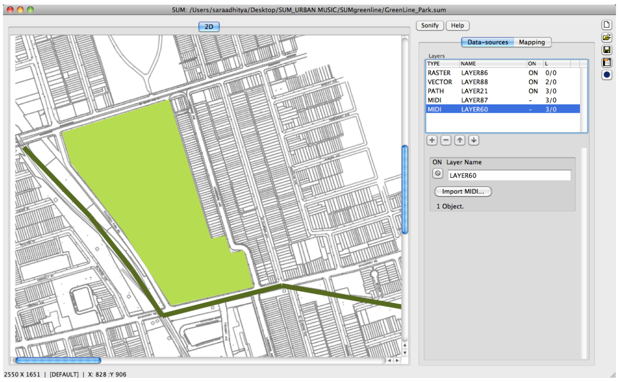

Figure 4. Imported raster image of site and drawn vector paths and areas of interest

4.2. MIDI-to-Path Mapping

The chosen music can then be mapped to the selected vector path using SUM's MIDI import function. We have chosen to map Steve Reich's *Piano Phase* [7], consisting of a two identical lines of music (a 12-tone melody) which are played at slightly different speeds so that they phase in and out. The MIDI file consists of two tracks, one for each piano part, shown in two different colors in the piano-roll below.

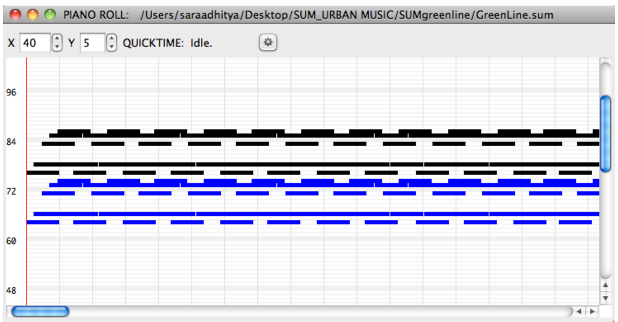

Figure 5. The MIDI file of Reich's Piano Phase represented as a piano-roll with two tracks (blue and black)

4.3. Graphical manipulation of MIDI path

After importation, we chose to maintain one MIDI path at the original speed to structure elements along the road, and manipulate the other path to generate a more flexible design for the park.

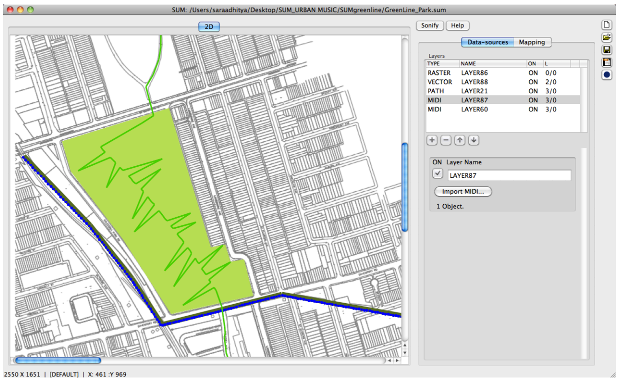

Figure 5. Reich's Piano Phase mapped along 2 paths of interest: a) along the road (blue), b) within the park (green)

The resulting piano roll shows the modified 'rhythm' of the modified park path, compared to the original rhythm of the linear road path.

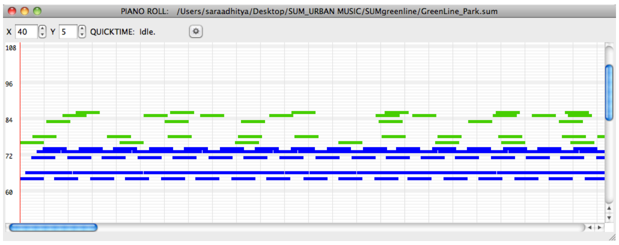

Figure 6. Piano roll showing the contrasting rhythms of the original path (blue) and the modified path (green)

4.4. Point-to-shape mapping

Finally, we apply the tree object created earlier using our Object Illustrator and saved in our SUM Object Library (see Figure 3). We map this object to the points of the park path, and use it to generate a tree layout for the park, shown in Figure 7 below.

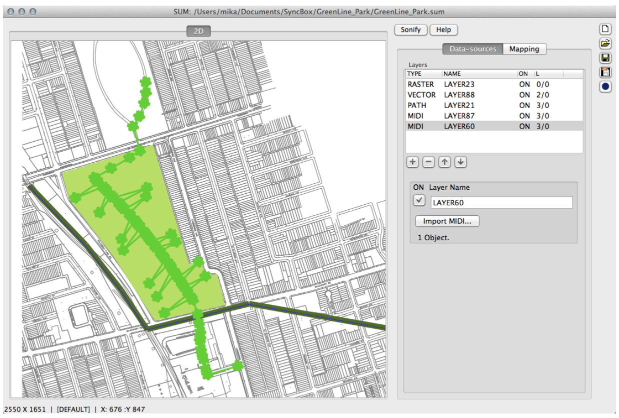

Figure 7. Resulting tree layout for the park

5. CONCLUSIONS

In this paper, we have explored the use of SUM as a design tool. Through the development of three new functions – MIDI import, temporal-manipulation of points, and the Object Illustrator – we have been able to map music as MIDI to user-defined vector graphics and subsequently modify them both spatially and temporally.

As an example, we applied these tools to an urban design project. We generated a tree layout for a park design based on Reich's *Piano Phase*. Thus this paper is also the beginning of an exploration of how music can be used to inform the composition of urban experience.

These developments have allowed us to develop the SUM tool, from an image-sonification tool and a music composition tool, to a graphical design tool. In the future, this approach could be used to generate a new graphical language for music representation.

6. ACKNOWLEDGEMENTS

The authors would like to thank IRCAM and CCRMA for hosting the research. The work of Sara Adhitya has been supported by the John Crampton Scholarship Trustees of Australia. The work of Mika Kuuskankare has been supported by the Academy of Finland (SA137619).

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